

Prepared for the  
GEORGE C. MARSHALL  
SPACE FLIGHT CENTER  
Huntsville, Alabama

31 August 1973

Contract No. NAS 8-14000  
MSFC No. MSFC-DRL-008A, Line Item 161  
IBM No. 73W-00253

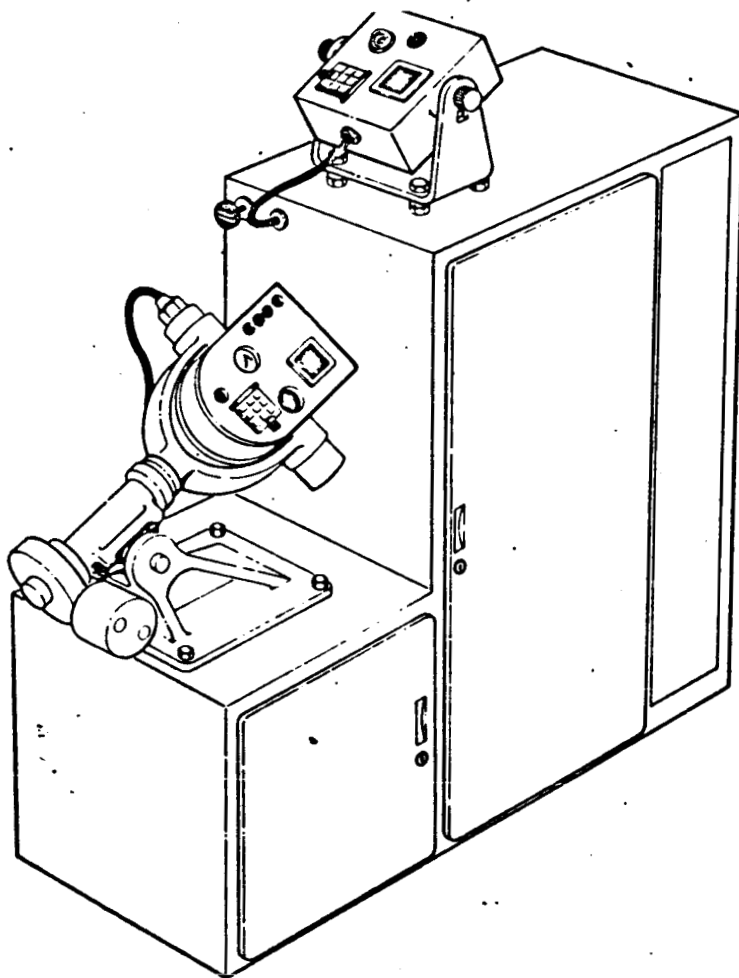
## SUNFALL MONITOR DESIGN STUDY

### Volume II - SYSTEM SPECIFICATIONS

(NASA-CR-161106) SUNFALL MONITOR DESIGN  
STUDY. VOLUME 2: SYSTEM SPECIFICATIONS  
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Volume II - SYSTEM SPECIFICATIONS

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# VOLUME II

## TABLE OF CONTENTS

### APPENDIX

### PAGE

A	Data Management Subsystem	
	Trade Off Studies .....	A-1
A-1	Summary .....	A-2
A-2	Study of Data Sampling Rate for Digital Integration of Sunfall Data .....	A-5
A-3	Initial Trade Off Study .....	A-13
A-4	Final Trade Off Study .....	A-48
B	Solar Tracker Subsystem Vendor	
	Evaluation .....	B-1
B-1	Vendor Evaluation .....	B-2
B-2	Vendor Selection .....	B-2
C	Sensor Characteristics .....	C-1
C-1	Summary .....	C-2

## VOLUME II

### LIST OF ILLUSTRATIONS

FIGURE	PAGE
A.2-1 Trapezoidal Integration .....	A-7
A.2-2 Pyranometer Output June 27, 1971 Newport, Rhode Island .....	A-10
A.2-3 Enlargement of 5:00 to 5:30 PM Data On Figure A.2-2 .....	A-11
A.2-4 Percent Error Versus Sample Rate .....	A-12
A.3-1 Analog Integration/FM Recording .....	A-15
A.3-2 Analog Integration/7 Track Digital Recording ....	A-16
A.3-3 Analog Integration/Digital Cassette Recording ...	A-17
A.3-4 A/D Conversion/7 Track Digital Recording .....	A-18
A.3-5 A/D Conversion/Digital Cassette Recording .....	A-19
A.3-6 FM Telemetry to Computer Facility .....	A-20
A.3-7 On-Site Calculator/Printer .....	A-21
A.3-8 Digitrend/7 Track Digital Recording .....	A-22
A.3-9 Digital Telemetry to Computer Facility .....	A-23
A.3-10 Weather Measure Digital Data Logger .....	A-24
A.4-1 Esterline Angus Model D-2020 Digital Data Logger .....	A-51
A.4-2 Functional Elements of D-2020 .....	A-52
A.4-3 Weather Measure M731-M9 Digital Logger .....	A-61
A.4-4 Kaye System 8000 Digital Data Logger .....	A-67
A.4-5 Metrodata DL 620 Modular Data Acquisition System .....	A-75
A.4-6 Metrodata DL 620/9 Track System Block Diagram .....	A-76
A.4-7 Datel LPS-16 Digital Data Logger .....	A-82

VOLUME II

LIST OF ILLUSTRATIONS

FIGURE		PAGE
A.4-8	Functional Block Diagram of Datel LPS-16 Data Logger .....	A-83
A.4-9	Metrodata DL 620 Modular Data Acquisition System .....	A-96
A.4-10	Metrodata DL 620/Cassette Tape System Block Diagram .....	A-97

# VOLUME II

## LIST OF TABLES

TABLE		PAGE
A.1-1	Data Management - Initial Trade Off Summary .....	A-3
A.1-2	Data Management Subsystem - Final Trade Off Summary .....	A-4
A.2-1	Sampling Rate According to Sampling Theory ..	A-8
A.3-1	Data Management Subsystem - Trade Off Options .....	A-14
A.3-2	Kennedy Model 1600-1610 Specifications .....	A-32
A.4-1	Data Management Subsystem Specifications ....	A-49
A.4-2	Data Management Subsystem - Final Trade Off Study .....	A-50
C.1-1	Sensor Characteristics - Tracking and Non-Tracking Assemblies .....	C-3

APPENDIX A

DATA MANAGEMENT SUBSYSTEM

TRADE-OFF STUDIES

## SECTION A-1

### SUMMARY

In order to determine which type of data management subsystem could meet the requirements listed in Table 2.2-1 most accurately and economically, an initial trade-off study was performed. An important input to this initial study was the rate at which the sensors need to be sampled to achieve a desired accuracy. Section A-2 of this appendix establishes the sensor sample rate of once every ten seconds as the required rate. The results of the initial trade off study, as presented in Table A.1-1 and discussed in Section A-3 of this appendix, was that an off-the-shelf complete digital data logger subsystem would best meet the requirements. Table A.1-2 summarizes the final trade off study where digital data logger systems were compared. This study, as presented in Section A-4 of this appendix, resulted in the choice of an Esterline Angus model D-2020 data logger system to meet all of the requirements for the data management subsystem as presented in Table 2.2-1. This study also produced an alternate data logger system, that could record for five days, at approximately one-half the cost of the Esterline Angus system. This data logger is manufactured by Metrodata Systems.

TABLE A. 1-1  
DATA MANAGEMENT SUBSYSTEM - INITIAL TRADE OFF SUMMARY

NUMBER	TITLE	TOTAL COST (DOLLARS)	PERCENT ERROR ( $\Delta T=10^{\circ}\text{C}$ )	MAJOR DISADVANTAGES	MAJOR ADVANTAGES
1	AI-FM	33,967	$\pm 1.10$	COST, ACCURACY LONG TERM STABILITY, PACK- AGING	NONE
2	AI-7T	18,898	$\pm 0.50$	COST, LONG TERM STABILITY, PACKAGING	OUTPUT IS DIRECTLY COMPUTER COMPATIBLE
3	AI-CAS	23,392	$\pm 0.50$	COST, LONG TERM STABILITY, CASSETTE CHANGER	NONE
4	A/D-7T	11,295	$\pm 0.02$	ASSEMBLY AND CHECK- OUT	COST, ACCURACY, LONG TERM STABILITY
5	A/D-CAS	15,789	$\pm 0.02$	CASSETTE CHANGER	ACCURACY, LONG TERM STABILITY
6	FM1-TEL	8,148*	$\pm 0.25$	PRIVATE LINE PHONE COST	REAL TIME DATA, RELIABILITY, OPERATIONAL SURVEILLANCE
7	ON-SITE	34,569	$\pm 0.13$	COST	SELF CONTAINED UNIT, PACKAGING
8	DIG-7T	11,834	$\pm 0.10$	ASSEMBLY AND CHECK- OUT	COST, PACKAGING, PROVEN DESIGN
9	DIG-TEL	11,488*	$\pm 0.10$	DIAL-UP PHONE LINE COST	COST, PACKAGING, PROVEN DESIGN
10	WM-LOG	16,727†	$\pm 0.10$	NONE	COST, MINIMUM CHECKOUT, COMPLETE SUBSYSTEM

\*COST OF PHONE LINE WILL BE ADDITIONAL DEPENDING ON STATION LOCATION

†COST INCLUDES FACTORY FABRICATION AND CHECKOUT

TABLE A.1-2

## DATA MANAGEMENT SUBSYSTEM - FINAL TRADE OFF SUMMARY

NUMBER	NAME	MODEL	COST	TRACKS	RECORDING TIME (15 HOUR DAYS)
1	Esterline Angus	D-2020	\$14,234.	9	40
2	Weather Measure	M731-M9	16,726.	9	29
3	KAYE	8001	16,623.	9	11
4	Metrodata	DL620	13,506.	9	37
5	DATEL (Cassette to 9-track one time hardware cost)	LPS-16	7,225.* 9,411.*	2	1.7
6	Metrodata (Cassette to 9-track one time hardware cost)	DL620	7,094. 9,965.	4	5.2

\*Assembly required

## SECTION A-2

### STUDY OF DATA SAMPLING RATE FOR DIGITAL INTEGRATION OF SUNFALL DATA

#### A-2.0 PURPOSE

The purpose of this study is to determine an optimum data sample rate for data received by the Sunfall Monitor, so that the digital integration of this data within the computer will provide an accurate output.

#### A-2.1 CONCLUSION

A sampling rate of once every ten (10) seconds is recommended for data collection from all sensors on the Sunfall Monitor. This recommendation is based upon the information presented in paragraph A-2.2 and the additional considerations listed below:

1. Even though cloud movement may sometimes vary at a high frequency, the amount of energy contained in a "spike" caused by this movement can be negligible in regards to the total integrated output.
2. Sampling all sensors at a rate of once every ten seconds and then recording this data on an incremental tape recorder can be accomplished with available recorders and tape lengths. Being able to record each channel of input data at one sample every ten seconds will eliminate the need for expensive on-site integration hardware which would be required for a sample rate of once every second, since sampling at this rate cannot be recorded within the required time on available recorders and tape lengths.
3. The sample rate of once every ten seconds will provide a maximum percent error of less than one percent by using the trapezoidal integration process as shown in equation (A-1).

$$\int_a^b f(x)dx \approx \Delta x \left[ \frac{f(a)}{2} + f(x_1) + \dots + f(x_{n-1}) + \frac{f(b)}{2} \right] \quad (A-1)$$

where:  $\Delta x = \frac{b-a}{n}$  = time between samples

$b-a$  = length of the integration period

$n$  = even number of samples taken within the integration period.

$f(a), f(x_1), \dots,$

$f(x_{n-1}), f(b)$  = sensor output value at each sample point.

Figure A.2-1 gives a pictorial representation of the integration process using the trapezoidal integration formula.

#### A-2.2 DESCRIPTION

The sampling rate of solar radiation data is a function of:

- 1)  $f_s$  = frequency response of sensor, and
- 2)  $f_c$  = frequency response of cloud movement.

The maximum frequency response of presently identified sensors are given below:

$f_s$ (pyranometer)	= 3 cycles/minute	[10 seconds to go from 10% to 90% fullscale]
$f_s$ (pyrheliometer)	= 5 cycles/minute	[6 seconds to go from 10% to 90% fullscale]
$f_s$ (solar cell)	= 500 cycles/second	[1 millisecond to go from 0% to 100% fullscale]

Data concerning the frequency response of cloud movement was not readily available, but by observation and discussion with Mr. Walter Scholes of Eppley Laboratories, the maximum frequency response of cloud movement was assumed to be about 7.5 cycles/minute which is faster than the frequency response of the pyranometer and pyrheliometer, but not the solar cell.

In order to determine the sampling rate to be used in the Sunfall Monitor the following items were taken into consideration. First, according to sampling theory, the minimum sampling rate should be twice the highest frequency that will be sensed by the sensors. This means that the sampling rate should be at least twice the maximum frequency response of the sensor ( $f_s$ ) or cloud movement ( $f_c$ ) which ever is the slowest. Therefore, to obtain accurate data from a pyranometer the minimum sampling rate should be 6 samples per minute (2 samples X 3 cycles/minute) or one sample every 10 seconds. The minimum sampling rate for pyrheliometer data should be 10 samples per minute (2 samples X 5 cycles/minute) or one sample every 6 seconds. The minimum sampling rate for solar cell should be determined by the frequency response of the cloud movement, since its frequency response is slower than that of the solar cell. Since the assumed maximum frequency response of cloud movement is 7.5 cycles/minute, the sampling rate for solar cell data would be 15 samples per minute (2 samples X 7.5 cycles/minute) or one sample every 4 seconds. This information is summarized in Table A.2-1.

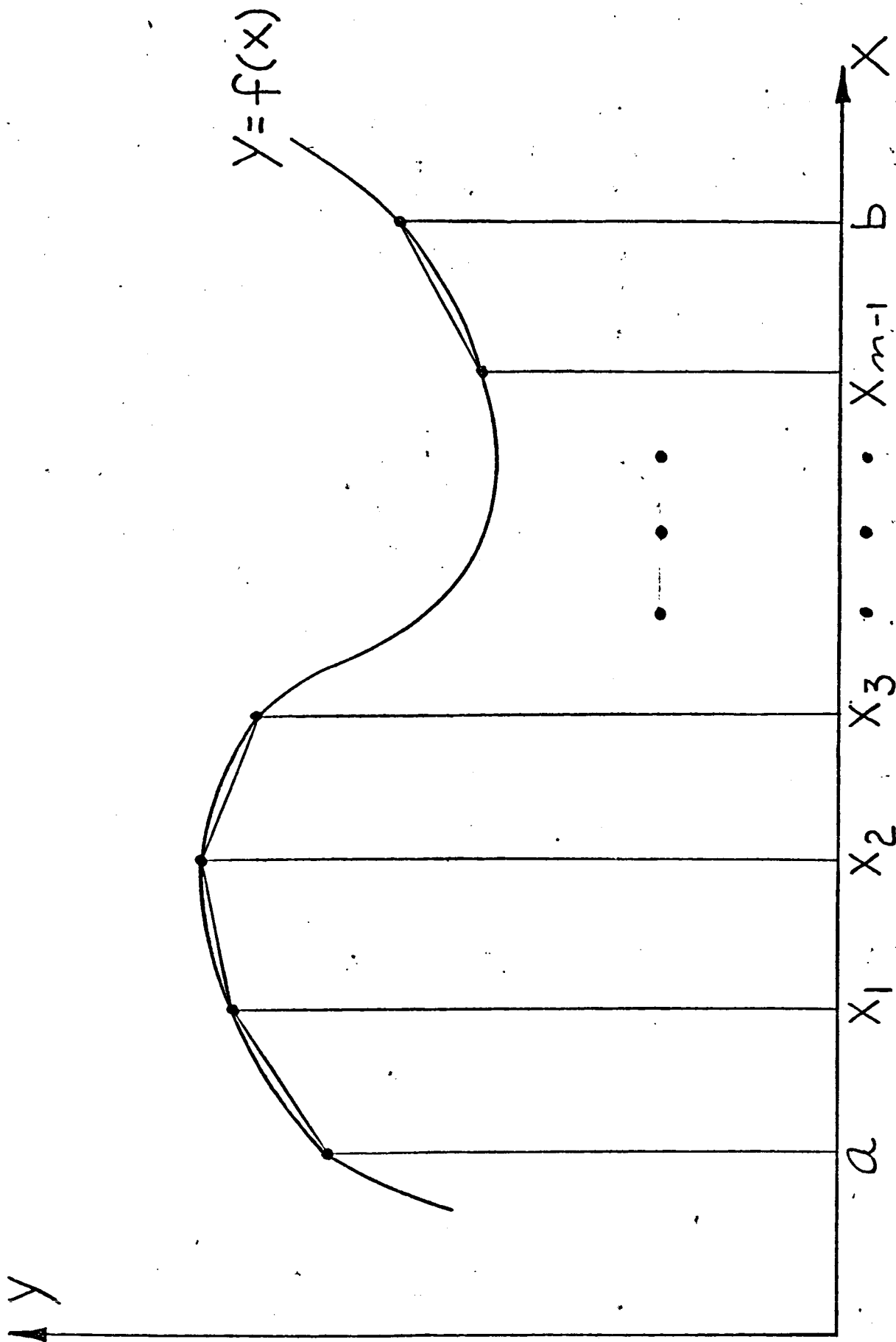


FIGURE A.2-1 TRAPEZOIDAL INTEGRATION

Table A.2-1  
SAMPLING RATE ACCORDING TO SAMPLING THEORY

SENSOR TYPE	NUMBER OF SAMPLES PER MINUTES	NUMBER OF SECONDS BETWEEN SAMPLES
PYRANOMETER	6	10
PYRHELIOMETER	10	6
SOLAR CELL	15	4

In order to evaluate the accuracy of the ten second sample rate, the output of a pyranometer, as shown in Figure A.2-2 was analyzed. The recorded output between 5:00 PM and 5:30 PM was enlarged as shown in Figure A.2-3, to allow data analysis to be performed. Sample data points were manually taken over the total thirty minute period for rates of 1, 2, 4, 6, 12, 20 and 30 samples per minute. By utilizing equation (A-1) the integrated area was determined and compared with the area determined by using a planimeter to give the percent error as shown in Figure A.2-4.

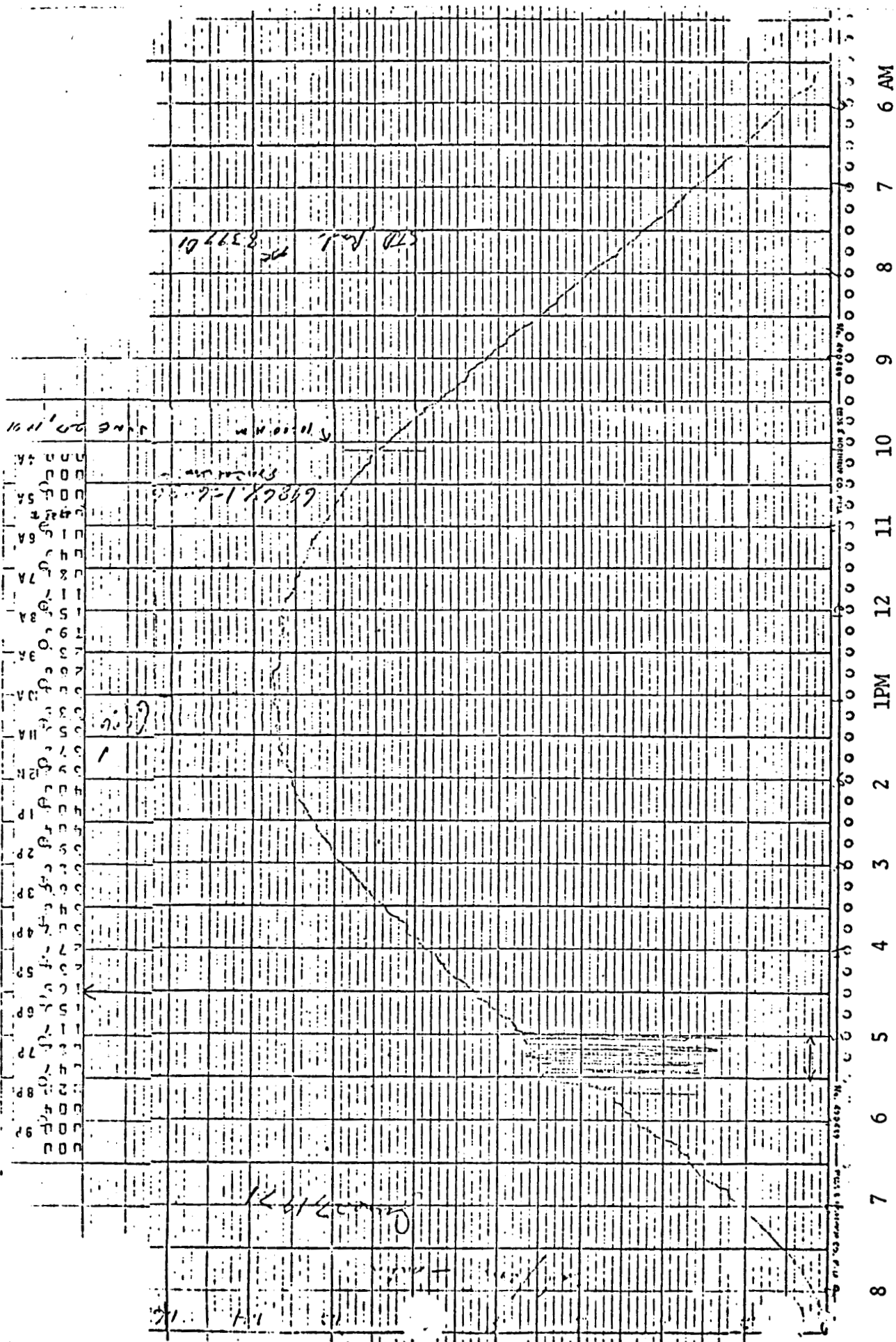


FIGURE A.2-2 PYRANOMETER OUTPUT JUNE 27, 1971 NEWPORT, RHODE ISLAND

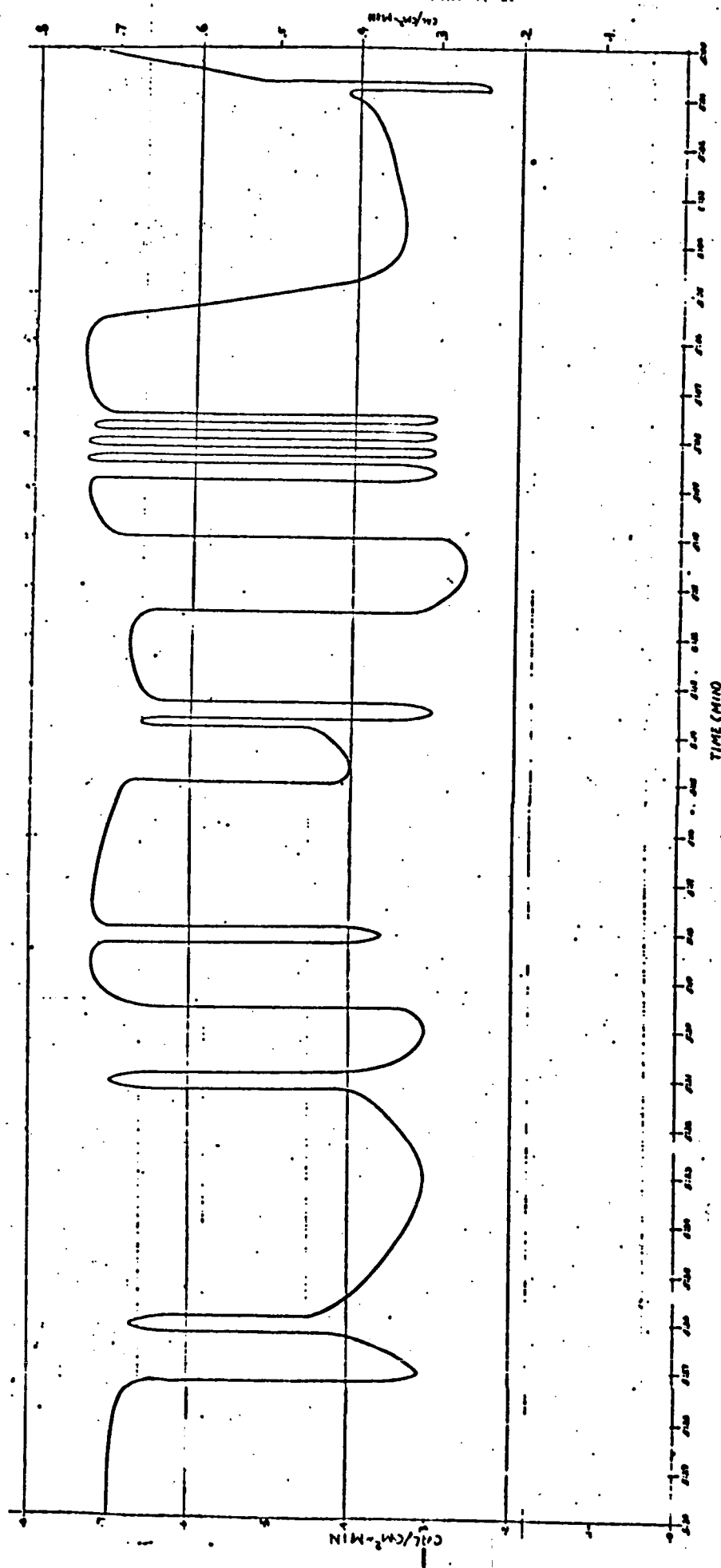


FIGURE A.2-3 ENLARGEMENT OF 5:00 TO 5:30 PM DATA ON FIGURE A.2-2

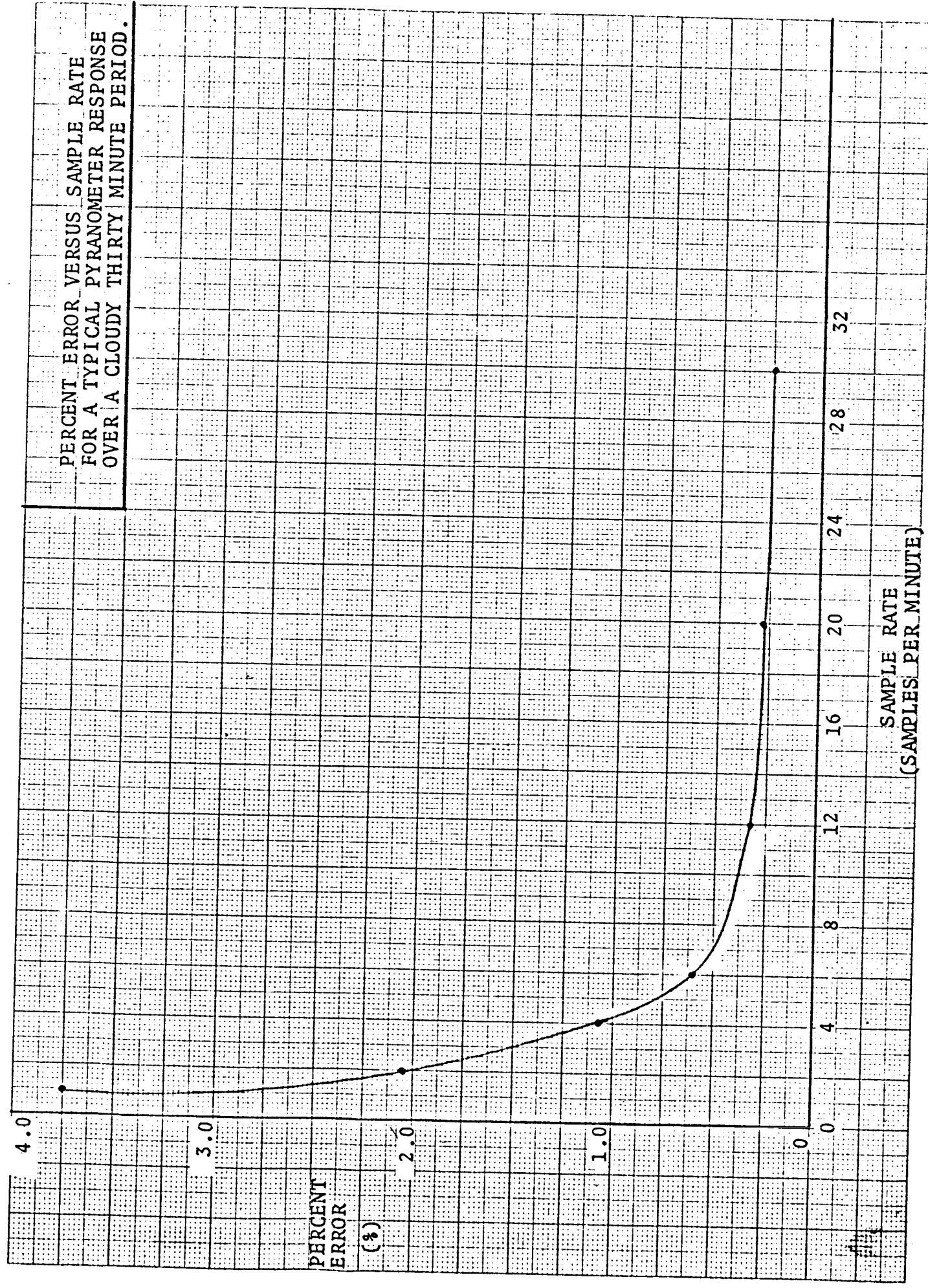
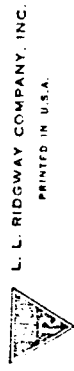


FIGURE A.2-4 PERCENT ERROR VERSUS SAMPLE RATE

## SECTION A-3

### INITIAL TRADE OFF STUDY

#### A-3.0 SUMMARY

An initial trade off study was performed to determine the type of data management subsystem to be used in the Sunfall Monitor. Table A.3-1 lists the different types of data management subsystems analysed. Of these ten different types, the digital data logger was determined to be the best system to meet Sunfall Monitor requirements. Figures A.3-1 to A.3-10 represent block diagrams of each type of data management subsystem analyzed in this initial trade off study.

#### A-3.1 ANALOG INTEGRATION/FM RECORDING

The block diagram of the analog integration/FM recording technique is shown in Figure A.3-1. The basic components of this type of data management subsystem are presented below. The major disadvantages of this type of system are cost, accuracy, long term stability and packaging. There are no major advantages.

##### A-3.1.1 Signal Conditioners

##### A) Instrumentation Amplifier - Burr Brown Model 3088/16

- 1) 10 Each
- 2) Basis of selection: Performance - good common mode rejection, adjustable gain, good temperature/drift stability; efficiently packaged, priced below most competitive amplifiers which usually have a higher slew rate and higher frequency response which is unimportant for this application.
- 3) Input  $z = 5 \times 10^{11} \Omega$ , gain 1 to 1100 variable.
- 4) Output:  $\pm 10$  Vdc, noise 6 mv rms @  $\beta = 1100$ ,  $30 \mu v$  @  $\beta = 1$
- 5) Dimensions: 3.5 x 1.063 x 7.03 inches
- 6) Temperature range: 0 to 60 degrees C
- 7) Power requirements:  $\pm 15$  vdc @  $\pm 35$  ma

##### B) Powered Rack Adapter - Burr Brown model 506/16

- 1) 1 Each
- 2) The rack will accommodate 10 of the 3088/16 amplifiers and supply necessary power and interface connections for the amplifier.
- 3) Input: 105-125 Vrms @ 50 to 400 Hz
- 4) Output voltage:  $\pm 15$  Vdc @  $\pm 100$  MA reg to  $\pm 0.1\%$

TABLE A.3-1

DATA MANAGEMENT SUBSYSTEM - TRADE OFF OPTIONS

NUMBER	TITLE
1	ANALOG INTEGRATION/FM RECORDING
2	ANALOG INTEGRATION/7 TRACK DIGITAL RECORDING
3	ANALOG INTEGRATION/DIGITAL CASSETTE RECORDING
4	A/D CONVERSION/7 TRACK DIGITAL RECORDING
5	A/D CONVERSION/DIGITAL CASSETTE RECORDING
6	FM TELEMETRY TO COMPUTER FACILITY
7	ON-SITE CALCULATOR/PRINTER
8	DIGITREND/7 TRACK DIGITAL RECORDING
9	DIGITAL TELEMETRY TO COMPUTER FACILITY
10	WEATHER MEASURE DIGITAL DATA LOGGER

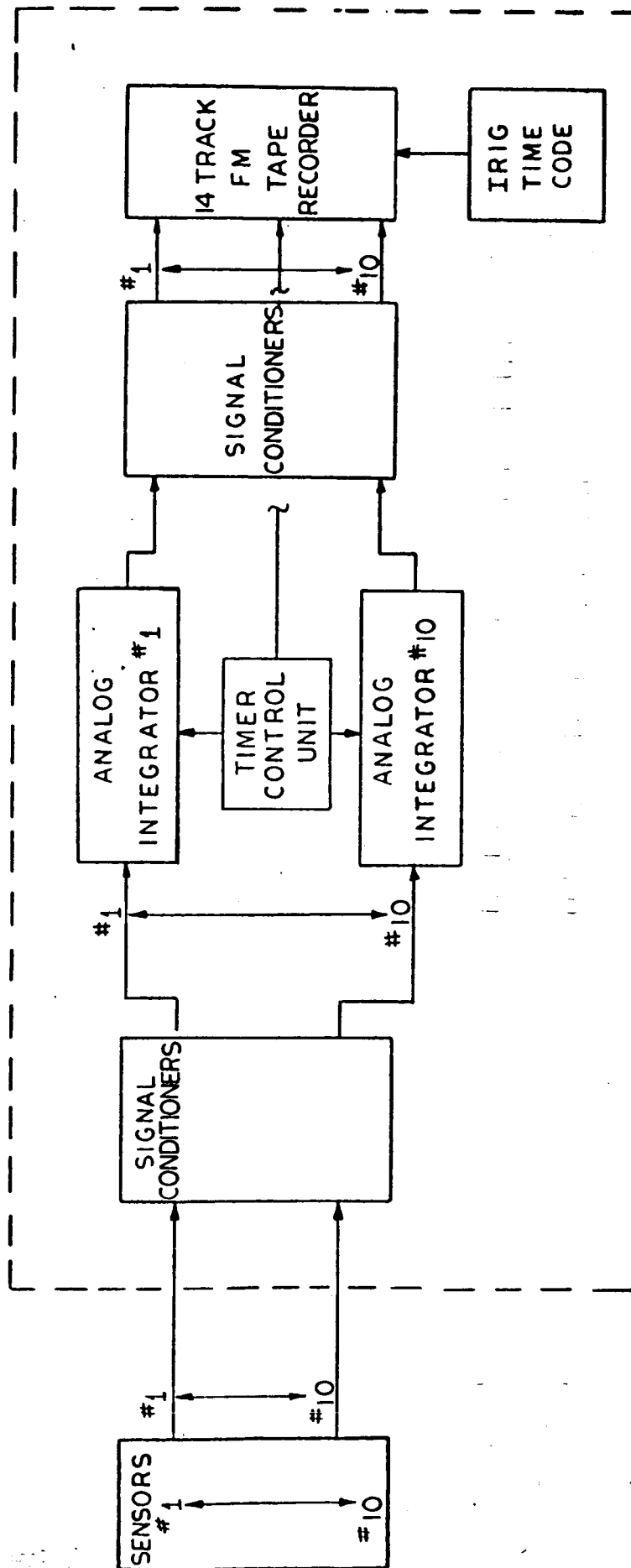


FIGURE A.3-1 ANALOG INTEGRATION/FM RECORDING

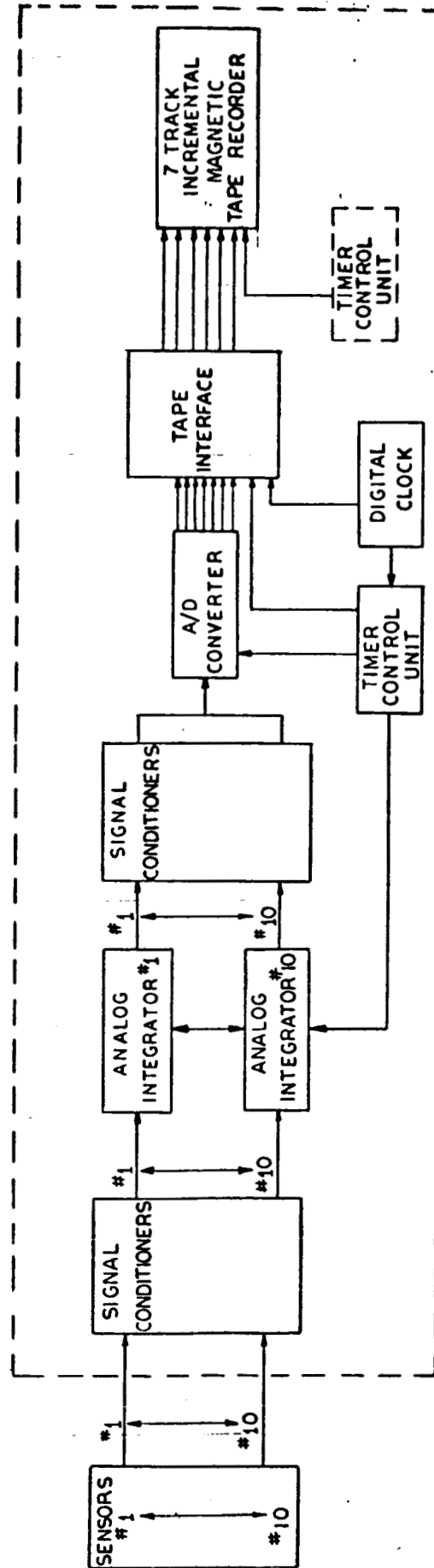


FIGURE A.3-2 ANALOG INTEGRATION/7 TRACK DIGITAL RECORDING

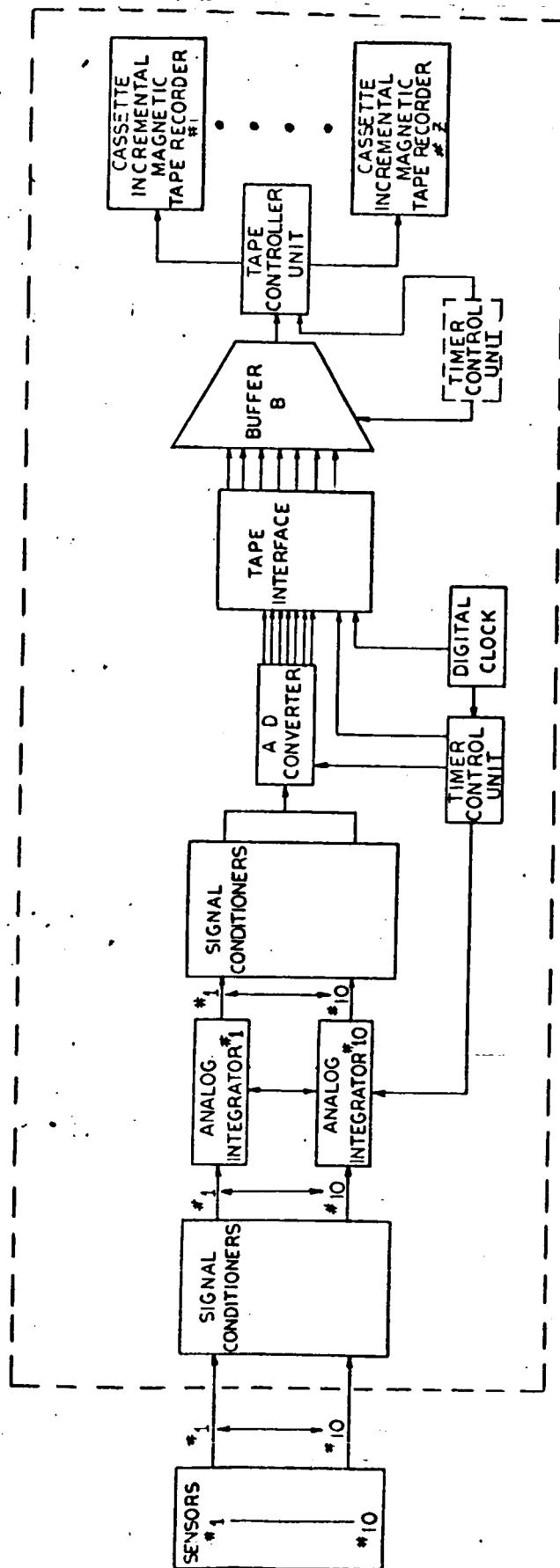


FIGURE A.3-3 ANALOG INTEGRATION/DIGITAL CASSETTE RECORDING

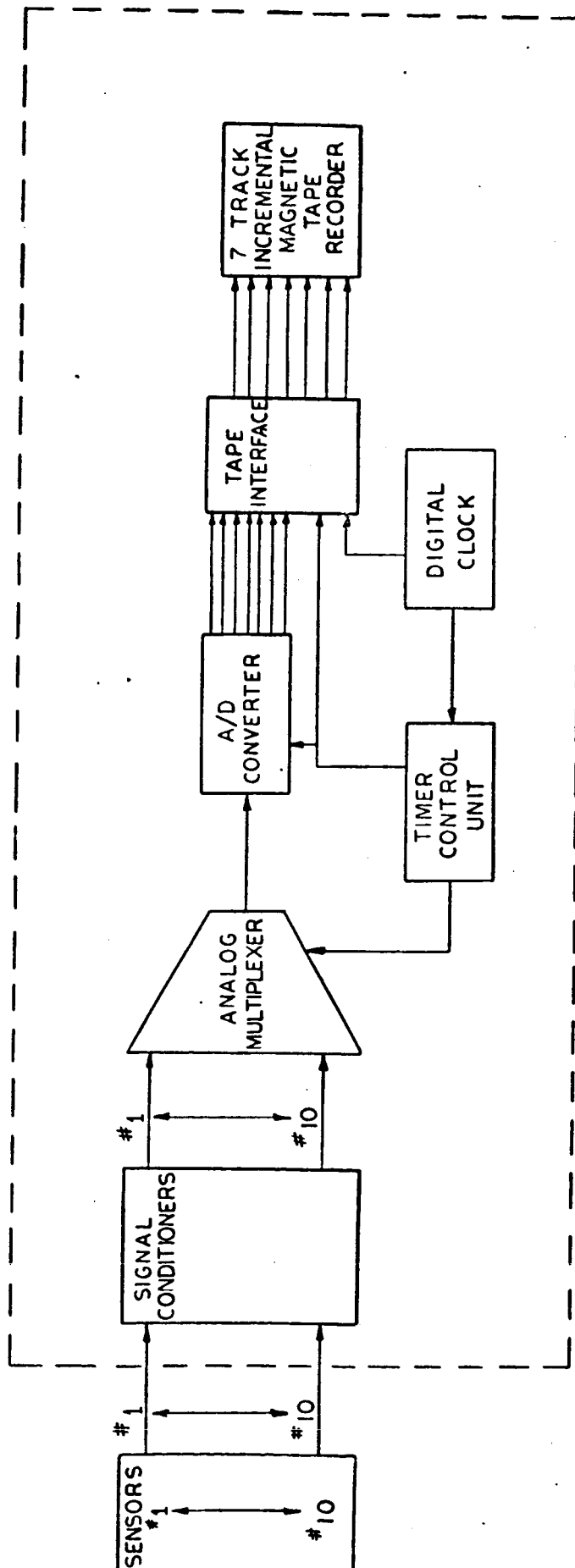


FIGURE A.3-4 A/D CONVERSION/7 TRACK DIGITAL RECORDING

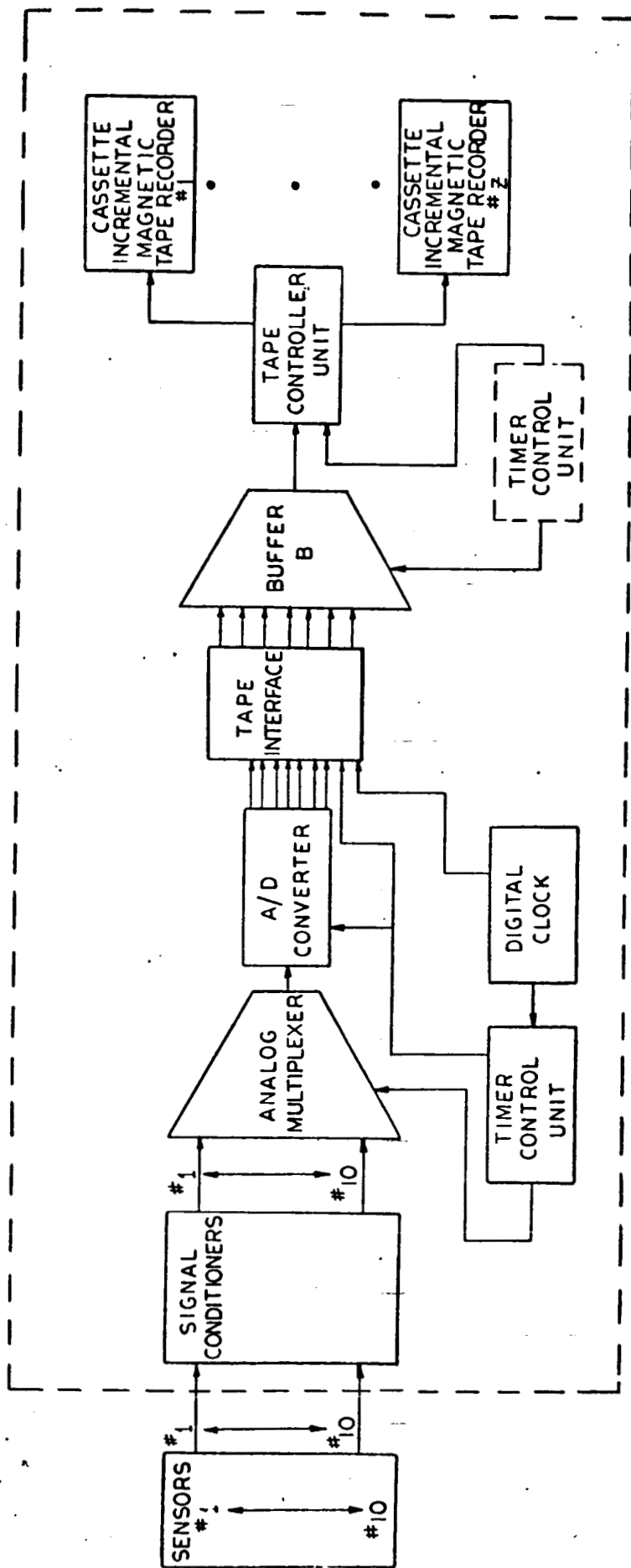


FIGURE A.3-5 A/D CONVERSION/DIGITAL CASSETTE RECORDING

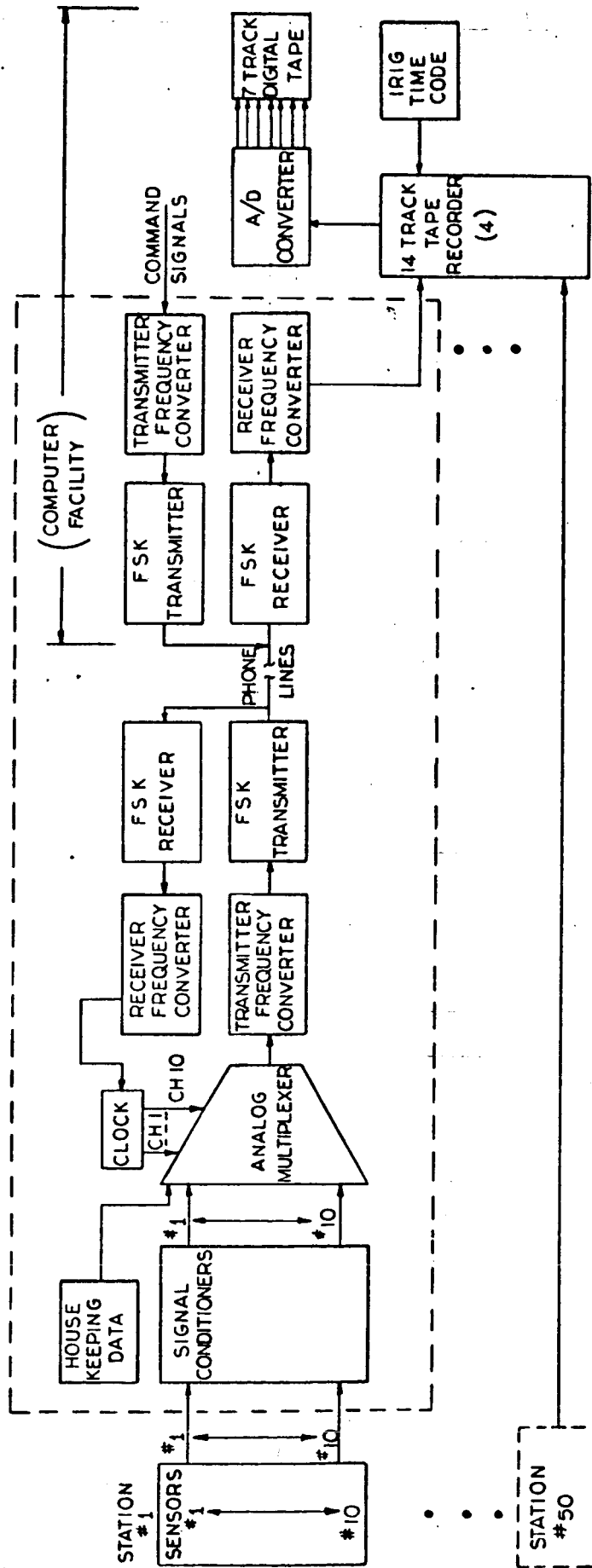


FIGURE A.3-6 FM TELEMETRY TO COMPUTER FACILITY

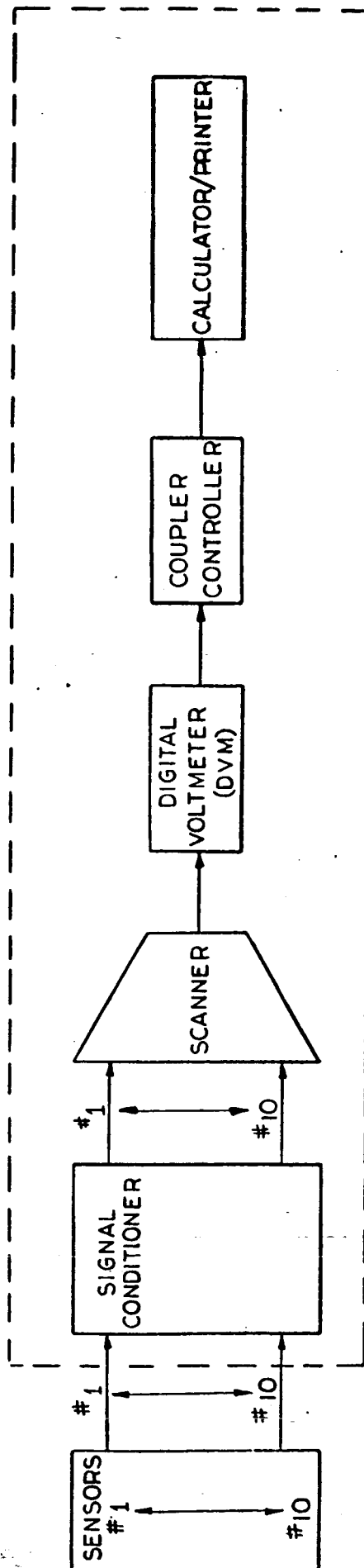


FIGURE A.3-7. ON-SITE CALCULATOR/PRINTER

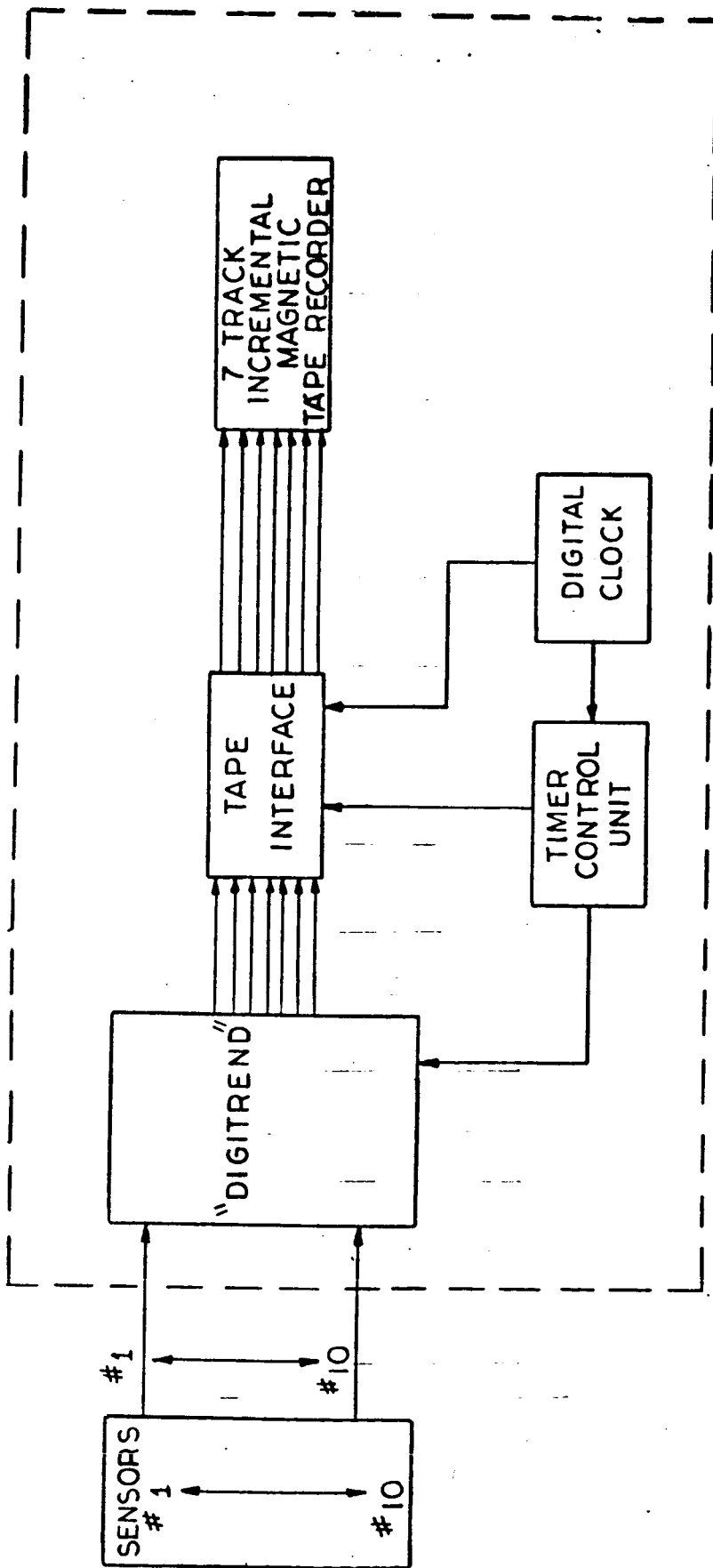


FIGURE A.3-8 · DIGITREND/7 TRACK DIGITAL RECORDING

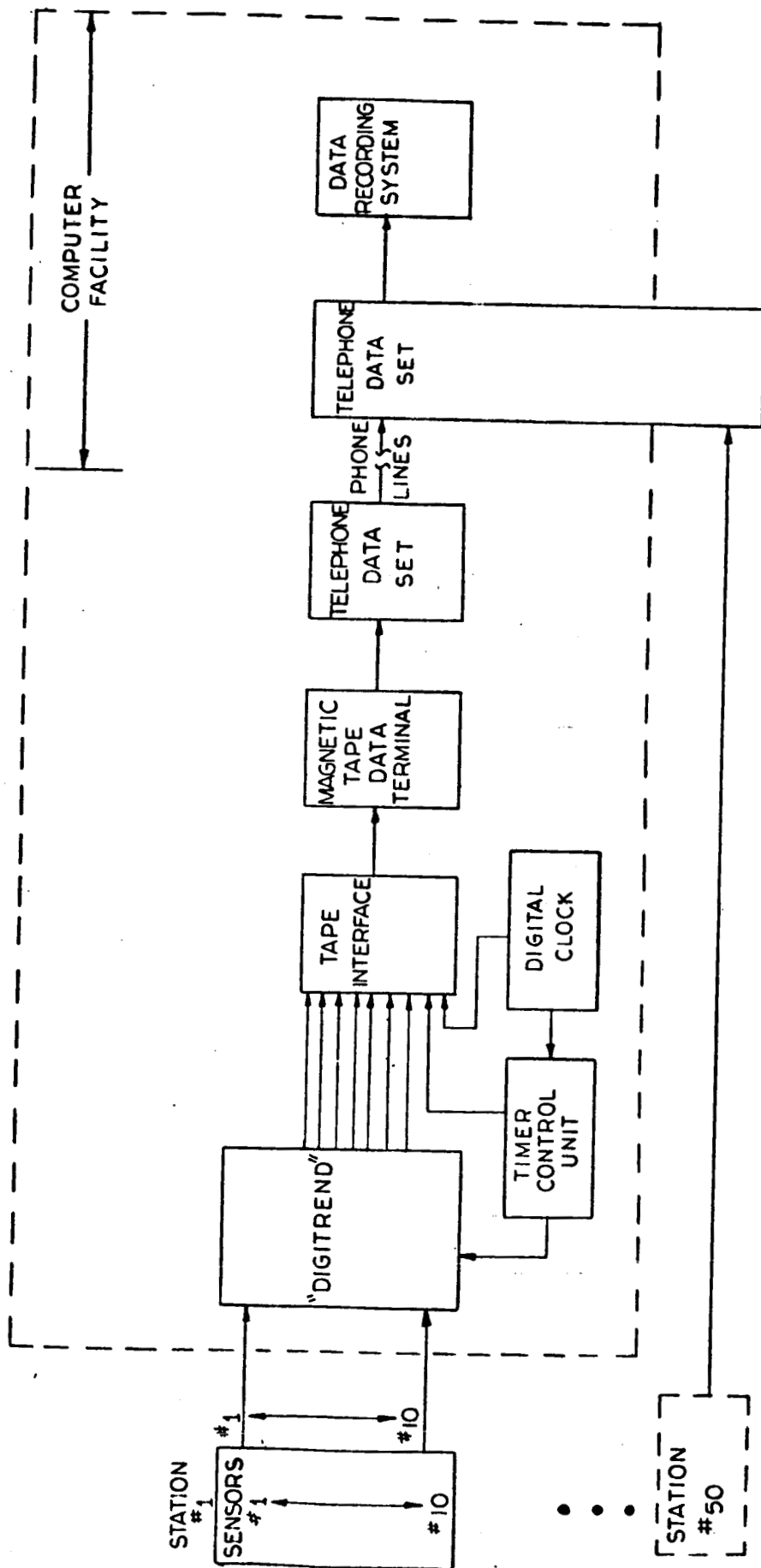


FIGURE A.3-9 DIGITAL TELEMETRY TO COMPUTER FACILITY

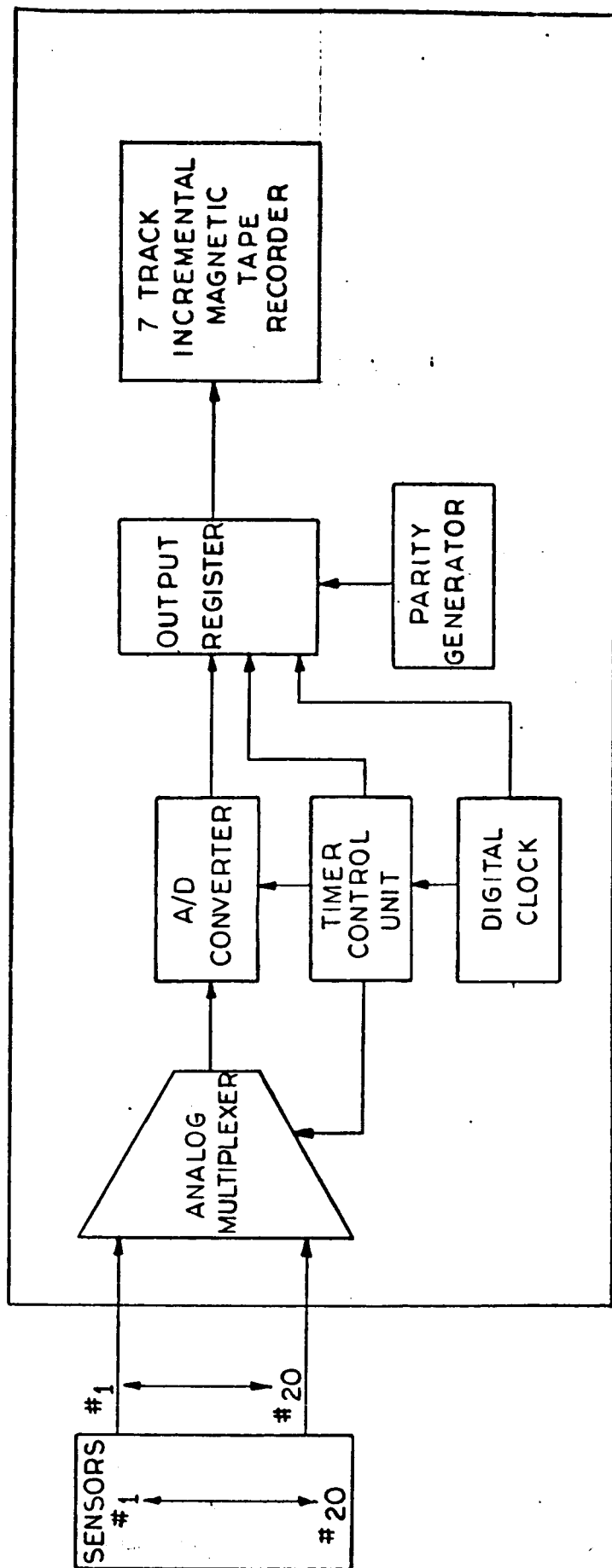


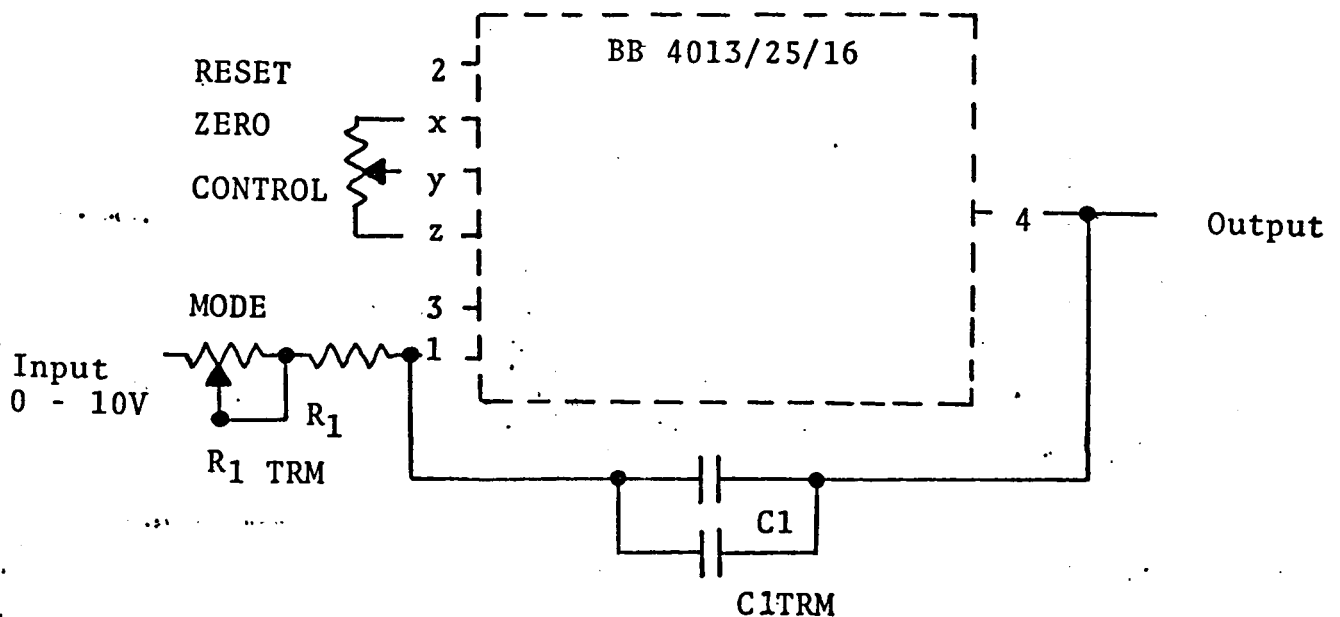
FIGURE A.3-10 WEATHER MEASURE DIGITAL DATA LOGGER

- 5) Rack is standard 19 in. instrument rack x 3.5" high x approximately 12" deep
- 6) Temperature range: -25 degrees C to +70 degrees C
- 7) Weight of rack + 10 amplifiers: approximately 25 pounds

C) Calibration Module

- 1) 1 Each
- 2) The calibration circuit will upon command remove the input signal from the instrumentation amplifier and inject a signal equal to 10% or 100% of the full scale span. This will give a complete calibration operation check of the entire data management subsystem exclusive of the sensors.
- 3) Input power will be supplied by long life mercury cell batteries which will be replaced annually.
- 4) The calibration module will be packaged via one channel slot in the power rack.

A-3.1.2 Analog Integrator



- 1) Component: Burr-Brown Research Corp (BB)  
Switched Integrator  
Model 4013/25/16
- 2) Trade-off logic: Compatibility with other BB components, namely racks, amplifiers and multiplexers

- 3) Specifications:
- o Voltage gain  $\frac{-1}{R_1 C_1}$
  - o Input voltage  $\pm 10\text{v}$
  - o Input impedance  $10\text{ K}\Omega$
  - o Output voltage  $\pm 10\text{ v Max}$
  - o Output current  $\pm 20\text{ ma}$
  - o Output impedance  $0.1\Omega$
  - o Output noise  $1\text{ mv rms}$
  - o Output drift @  $25\text{ degrees C}$   
 $\pm \frac{0.2}{C} \text{ mv/s}$
  - o Output drift vs.  $\pm 1\% \text{ P.S.}$   
 $\pm \frac{1.5}{C} \text{ mv/s}$
  - o Power  $\pm 15\text{ v}, \pm 70\text{ ma}$
  - o Rack Mounted
  - o Size  $61 \times 46 \times 15.3\text{ (mm)}$
  - o Weight  $120\text{ grams}$
  - o Gain Accuracy at dc max  $\pm 0.1\% \text{ FS}$
  - o Input/Output feedthrough error  
max  $\pm 1\text{ mv}$
  - o Requires external zero control  
pot for offset voltage adjustment
  - o Output offset vs. temp  $\pm 100$   
 $\mu\text{v/degree C vs P.S. } \pm 0.4\text{ mv/\%}$

4) External resistor and capacitor:

For integration period of 1 minute: (longer periods not practical)

- o Time constant ( $T_0$ ) must approximate  
100 times the period of the lowest  
input frequency component for  
proper averaging
- o For a  $T_0$  of 6000 seconds,  $R_1$   
could be 1 megohm and  $C_1$  could  
be 6000  $\mu\text{f}$

- o Gain would be  $= \frac{-1}{R_1 C_1} = -0.00017$
- o Gain accuracy is determined by precision of  $R_1$  and  $C_1$
- o Gain stability is determined by temp/drift characteristics of  $R_1$  and  $C_1$ .

5) Problem areas with analog integration for 1 minute

- o For 1% of accuracy of  $T_0$ , capacitor and resistor trimmers must be utilized, with final adjustment performed during system checkout.
- o Gain stability and accuracy of  $T_0$  is dependent on temperature characteristics of  $R_1$ , and  $C_1$  and the trimmers, and the stability of the environmental control system.
- o Errors in system will be integrated along with input signal.

A-3.1.3 Timer Control Unit

The timer control unit was to be an internal IBM designed and built piece of hardware.

- 1) TTL dips - chosen for cost, flexibility, ease of assembly and testing.
- 2) Weight (pounds):
 

TTL -	0.25
Wire -	2.00
Boards -	0.75
Sockets -	1.00
Frame -	<u>4.00</u>
Total	7 pounds
- 3) Dimensions: 19" W x 12.6" D x 2.7" H
- 4) Power: 3 Watts at  $\pm 5$  VDC

#### A-3.1.4 IRIG Time Code Generator

The Datametrics IRIG time code generator, model SP-175, will provide the day, hour, minute, and second signals for recording on the magnetic tape for the purpose of time correlating the solar radiation data.

#### A-3.1.5 14 Track FM Tape Recorder

After reviewing tape recording equipment made by Ampex, Hewlett Packard, and Sangamo, the model FR2000 by Ampex and the model 3614 Sabre III by Sangamo were reviewed in detail. The final choice of these two recorders was the Sangamo recorder with the following specifications:

- 1) Tape Speed: 15/16 IPS
- 2) Reel Size: 16 Inch
- 3) Tape Width: 1 Inch
- 4) Tape Length: 12,500 Ft.
- 5) Input Sensitivity: 0.2 to V rms; adjustable in two ranges with vernier overlap for full deviation. Three position selector; 0.2 to 15. V; 1.5 to 10.0 V, or Test.
- 6) Nominal Input Level: 1.0 V rms.
- 7) Nominal Input Impedances: 125,000 ohms resistive (1.5 to 10 V range). 20,000 ohms resistive (0.2 to 1.5 V range). All shunted by less than 100 pF, unbalanced to ground. Other loading values available on special order.
- 8) DC Drift: Less than  $\pm 0.5\%$  of peak-to-peak deviation over an 8 hour period for 10 degrees C after 15 minute warmup.
- 9) DC Linearity: Less than  $\pm 0.5\%$  of peak-to-peak deviation referenced to best straight line.
- 10) Total Harmonic Distortion (All Speeds): Less than 0.5% for frequencies lower than  $0.1F_{co}$  for all IRIG low intermediate, and wideband Group I; less than 1.0% for wideband Group II.
- 11) Output Level (Full Deviation): Adjustable to 1.0 V rms nominal into 75 ohms, with short circuit protection. (SCP).

- 12) Output Impedance: 50 ohms nominal, unbalanced to ground with SCP.
- 13) Output Squelch: Automatic for all speeds and activated from FM carrier detector or transport synchronous logic.

#### PHYSICAL CONFIGURATION

- 14) Size: 26 inches high by 19 inches wide by 11 1/2 inches deep. Additional enclosure required (7 inches high) for a 14 channel 7 speed FM switchable record/reproduce system.
- 15) DC Power: Switchable between 28  $\pm$ 2 VDC and 24  $\pm$ 2 VDC (15 and 16 inch reels not applicable on 24 VDC): optional DC power supply for operation from 47 to 440 Hz at 105 to 240 V ac.
- 16) DC Power Supply Size: 7 inches high by 19 inches wide by 11 5/8 inches deep.
- 17) Weight: Approximately 100 pounds. Optional DC power supply weighs approximately 40 pounds.

#### GENERAL

- 18) Environment: Designed for laboratory, field van, shipboard, automotive and aircraft.
- 19) Temperature: Operating Range 5° to 50°C.
- 20) Humidity: 5 to 95% relative, non-condensing.
- 21) Altitude: 30,000 feet operating: 70,000 feet non-operating.
- 22) Standard Colors: Front door and cabinet - Olive. Front trim and card fronts - Beige.
- 23) Accuracy: 1%.
- 24) Signal-to-Noise Ratio: 41db.

#### A-3.2 ANALOG INTEGRATION/7 TRACK DIGITAL RECORDING

The block diagram of the analog integration/7 track digital recording technique is shown in Figure A.3-2. The major disadvantages are cost, long term stability, and packaging. The major advantage is that the output is directly computer compatible. The basic components of this type of data management subsystem are presented below.

- A-3.2.1 Signal Conditioners (See Paragraph A-3.1.1)
- A-3.2.2 Analog Integrator (See Paragraph A-3.1.2)

A-3.2.3     Timer Control Unit (See Paragraph A-3.1.3)

A-3.2.4     Digital Clock

The Anadex model CK-610 digital clock was chosen to supply accurate time in days, hours, and minutes.

A-3.2.5     A/D Converter

A Datel Systems A/D converter, ADC-EH10B, with the specifications below will be used in this configuration.

- 1)     Input:   0 to 10 VDC
- 2)     Output:   TTL compatible
- 3)     Size: 2" W x 3" D x 3/8" H
- 4)     Weight:   4 ounces
- 5)     Accuracy:    $\pm 1/2$  LSB,  $\pm .05\%$
- 6)     Power :     .5 Watts at  $\pm 15$  VDC  
                 1.4 Watts at  $\pm 5$  VDC
- 7)     Trade Off: 10 bit resolution for accuracy, meets or exceeds capabilities of other A/D converters at lower cost.

A-3.2.6     Tape Interface

The tape interface for the data management subsystem configuration was to be an internal IBM designed and built piece of hardware.

- 1)     TTL dips - chosen for cost, flexibility, ease of assembly and testing.
- 2)     Weight (pounds):  

TTL -	0.25
Wire -	5.00
Boards -	0.75
Sockets -	1.00
Frame -	<u>4.00</u>

Total           11.00 pounds
- 3)     Dimensions: 19" W x 12.6" D x 2.7" H
- 4)     Power: 15 Watts at  $\pm 5$  VDC

#### A-3.2.7 7 Track Incremental Magnetic Tape Recorder

Three incremental magnetic tape recorders were reviewed for possible utilization in this configuration. These recorders were the Kennedy model 1610, Pertec model 2807, and the Cipher model 100M. For this particular configuration the Kennedy model 1610 was chosen with the specifications as shown on the Kennedy bulletin IR-101/270. This bulletin is shown in Table A-5.

#### A-3.3 ANALOG INTEGRATION/DIGITAL CASSETTE RECORDING

The block diagram of the analog integration/digital cassette recording technique is shown in Figure A.3-3. The major disadvantages are cost, long term stability, and the cassette changer. There are no major advantages. The basic components of this type management subsystem are presented below.

##### A-3.3.1 Signal Conditioners (See Paragraph A-3.1.1)

##### A-3.3.2 Analog Integrator (See Paragraph A-3.1.2)

##### A-3.3.3 Timer Control Unit (See Paragraph A-3.1.3)

##### A-3.3.4 Digital Clock (See Paragraph A-3.2.4)

##### A-3.3.5 A/D Converter (See Paragraph A-3.2.5)

##### A-3.3.6 Tape Interface (See Paragraph A-3.2.6)

##### A-3.3.7 Buffer B

This buffer would be designed and built by IBM to accept a time code and ten serial words, where each word contains ten bits in parallel. These would be serialized for output to the cassette recorder via the tape controller unit. This buffer can be built easily and economically with TTL dips and mounted on the timer control panel. Timing functions would be supplied by the timer control unit.

##### A-3.3.8 Tape Controller Unit

This unit would be designed and built by IBM to accept the time code and serialized data from buffer B for output to the active cassette recorder. Once a cassette unit is filled up with data the tape controller unit would activate the next unused cassette unit and route the data to the newly activated unit.

##### A-3.3.9 Cassette Incremental Magnetic Tape Recorder

Five cassette incremental magnetic tape recorders were reviewed for possible utilization in this configuration. These recorders were the Bell and Howell, Ampex model TMC-1, Kennedy model 330, Electronic Processors model STR-200I, and the Memodyne model UIW-101E. For this configuration the Memodyne model UIW-101E was chosen with the following specifications:

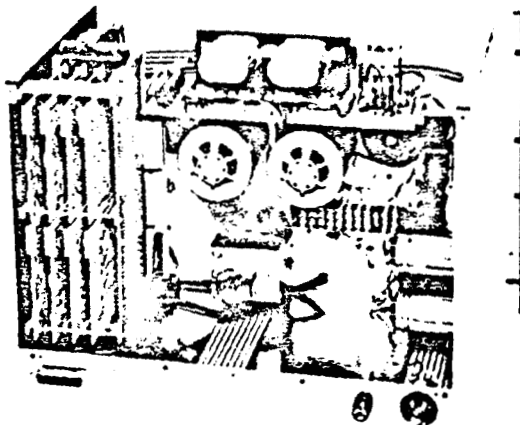
# KENNEDY CO.

540 West Woodbury Road, Altadena, California 91001 • (213) 798-0953

TABLE A.3-2

## Kennedy Model 1600-1610 Specifications

### SPECIFICATIONS/MODELS 1600/1610



#### GENERAL

Write Rate:	0-300 characters/second (0-500 characters/second Model 1610)
Density:	200, 556, 800 BPI $\pm 3\%$ (specify one)
Inter-Channel Displacement Error:	200, 556 — $\pm 200$ microinches 800 BPI — $\pm 150$ microinches
Tape Format:	7-track, IBM compatible NRZI
Reel Size:	Model 1600 — 8½ inches Model 1610 — 10½ inches, ½-inch standard computer tape 1.5 mil
Rewind Time:	Model 1600 — less than 2 minutes Model 1610 — less than 3 minutes
Tape Tension:	2 ounces

#### GAPS AND MARKS

Inter-Record Gap:	¾ inch IRG automatically generated upon external command. IRG time is less than 180 ms at 200 BPI, 470 ms at 556 BPI, and 550 ms at 800 BPI.
File Gap:	Standard 3½-inch file gap automatically generated upon external command or by front panel pushbutton.
File Mark:	Standard binary 15 File Mark written at conclusion of file gap. File Mark is followed automatically by ¾ inch Record gap.
Beginning of Tape Gap:	In loading operation, BOT marker is sensed and ½ inch gap is automatically inserted.
Vertical Parity:	Internally generated and recorded in track C. Odd or Even parity is selected by external level.
Longitudinal Parity:	Internally generated. LCC is written properly spaced from end of record.

#### FRONT PANEL CONTROLS

Load Forward:	Automatically advances tape to load point and inserts BOT. After load operation, pressing this button causes tape to be advanced at 1000 steps per second.
Power:	ON/OFF
Ready:	Indicates that machine is ready to accept data. Machine achieves Ready

status upon passing Load Point marker. If READY button and LOAD FORWARD button are pressed simultaneously, Ready status is achieved without marker. Pressing this button causes a file gap to be inserted.

#### File Gap:

#### Rewind:

#### Remote Controls:

Initiates rewind motion. Rewind cannot be stopped until Load Point marker is reached, whereupon stop is automatic.

All controls are brought out for remote operation.

#### INTERFACE REQUIREMENTS

##### Inputs:

Standard interface is DTL compatible with current sinking positive logic having a "one" level of +4V to +6V and a "zero" level of 0V  $\pm 0.5V$ . All functions, except remote controls which require closures to ground, are initiated by "one" levels. "Zero" levels should be capable of sinking 5 ma.

##### Outputs:

Outputs generated have "one" levels of +5V  $\pm 1V$  with a source impedance of 3K. Outputs will sink at least 10 ma. These lines may be modified to +10V by removing internal clamps.

##### Power:

115/230VAC, 50/60 HZ, 150 VA

#### PHYSICAL REQUIREMENTS

##### Size:

Model 1600:  
19" wide x 12¼" high x 10" deep  
Model 1610:  
19" wide x 24½" high x 10" deep

##### Mounting:

Standard Retma Rack

##### Weight:

Model 1600:  
40 lbs. Shipping weight: 55 lbs.  
Model 1610:  
70 lbs. Shipping weight: 98 lbs.

##### Finish:

Charcoal Gray  
FED STD 595-26440

#### ENVIRONMENTAL

##### Temperature:

Operating: 0°C to 50°C  
Non-operating: -10°C to 65°C

##### Humidity:

15% to 95% non-condensing

##### Altitude:

Operating: 20,000 ft.  
Non-operating: 40,000 ft.

#### OPTIONS AVAILABLE

1. Write Rate: 0-500 characters/second (Mod. 1600), 0-750 characters/second, 0-1500 characters/second
2. Fast IRG: Less than 70 ms
3. Negative Logic:
4. Special Paint:

#### ACCESSORIES SUPPLIED WITH EACH RECORDER

1. Mating Connector:
2. Power Cord:
3. 1 each Operation and Maintenance Manual
4. Empty Take-up Reel

For complete interface information send for Model 1600/1610 Interface Guide.

1. Model: UIW-101E
2. Description: Unidirectional Incremental Write
3. Record Media: Standard Phillips Type Certified Digital Cassette
4. Number of Tracks: 2
5. Recording density: 860 BPI
6. Write speed: 0-100 steps/second
7. Input Power: +12 VDC,  $\pm 5\%$  at 70 ma operating and 2 $\mu$ a standby.
8. Physical size: 4.7" L x 5.5" W x 4.4" H
9. Weight: 1.75 pounds

For this configuration calculations indicate that fifteen of the tape units specified above would be required to record one month of data.

#### A-3.4 A/D CONVERSION/7 TRACK DIGITAL RECORDING

The block diagram of the A/D conversion/7 track digital recording technique is shown in Figure A.3-4. The major disadvantages are assembly and checkout. The major advantages are cost, accuracy, and long term stability. The basic components of this type of data management subsystem are presented below.

##### A-3.4.1 Signal Conditioners (See Paragraph A-3.1.1)

##### A-3.4.2 Analog Multiplexer

The analog multiplexer will be a Burr Brown model 4047-43.

- (1) One each
- (2) The B-B 4047/43 was selected because of: compatibility with the 3088/16 amplifier, commonality of power requirements, commonality of environmental requirements and cost.
- (3) Input (analog)  $\pm 15$  V,  $Z_{in}$  on mode  $400\Omega$ , off mode  $10^{10}\Omega$ , leakage 100 pA  
(Digital) on mode 2.2 min  $\pm 10$  V max, off mode 0.8 V max,
- (4) Output:  $\pm 10$  V @  $\pm 10$  mA noise 1 mV rms max
- (5) Temp range 0 to 60 degrees C.
- (6) Power requirements  $\pm 15$  VDC @ +37 mA and -36 mA per channel
- (7) Weight approximately 0.5 pound

- A-3.4.3     Timer Control Unit (See Paragraph A-3.1.3)
- A-3.4.4     Digital Clock (See Paragraph A-3.2.4)
- A-3.4.5     A/D Converter (See Paragraph A-3.2.5)
- A-3.4.6     Tape Interface

The tape interface for this configuration was to be an internal IBM designed and built piece of hardware.

- 1)     TTL dips - chosen for cost flexibility, ease of assembly and testing

- 2)     Weight (pounds):

TTL -	1
Wire -	20
Boards -	2
Sockets -	4
Frame -	<u>4</u>

31 pounds

- 3)     Dimensions:     19" W x 12.6" D x 2.7" H

- 4)     Power:     15 Watts at  $\pm 5$  VDC

- A-3.4.7     7 Track Incremental Magnetic Tape Recorder  
(See Paragraph A-3.2.7)

#### A-3.5     A/D CONVERSION/DIGITAL CASSETTE RECORDING

The block diagram of the analog-to-digital conversion/digital cassette recording is shown in Figure A.3-5. The major disadvantage is the cassette changer. The major advantages are accuracy and long term stability. The basic components of this type of data management subsystem are presented below.

- A-3.5.1     Signal Conditioners (See Paragraph A-3.1.1)
- A-3.5.2     Analog Multiplexer (See Paragraph A-3.4.2)
- A-3.5.3     Timer Control Unit (See Paragraph A-3.1.3)
- A-3.5.4     Digital Clock (See Paragraph A-3.2.4)

- A-3.5.5     A/D Converter (See Paragraph A-3.2.5)
- A-3.5.6     Tape Interface (See Paragraph A-3.4.6)
- A-3.5.7     Buffer B (See Paragraph A-3.3.7)
- A-3.5.8     Tape Controller Unit (See Paragraph A-3.3.8)
- A-3.5.9     Cassette Incremental Magnetic Tape Recorder  
(See Paragraph A-3.3.9)

#### A-3.6        FM TELEMETRY TO COMPUTER FACILITY

The block diagram of the FM telemetry to computer facility technique is shown in Figure A.3-6. The major disadvantage is the private phone line cost. The major advantages are real time data, reliability, and operational surveillance. The basic components of this type of data management subsystem are presented below.

##### A-3.6.1     Signal Conditioners

- 1)     10 Low level converters - Bristol Model 3750052-02-1
- 2)     This converter was selected on the basis of:  
Packaging compatibility and power requirement  
compatibility with the other Bristol components  
used in this system, performance is compatible  
with other system components, good temperature  
stability and low cost.
- 3)     Input (Analog)  $\pm 15$  V,  $Z_{in}$  - on mode  $400\Omega$ , off mode  $10^{10}\Omega$ ,  
leakage 100 pA, (Digital) on mode 2.2 V min  $\pm 10$  V  
max, off mode 0.8 V max
- 4)     Output:     $\pm 10$  V @  $\pm 10$  mA, noise 1 mV rms max
- 5)     Temp range:   0 to 60 degrees C
- 6)     Power requirements  $\pm 15$  Vdc @ 37 mA and -36 mA per  
channel
- 7)     Weight:    Approximately 0.5 pound

##### A-3.6.3     Transmitter - Receiver Frequency Converter

- 1)     4 each - Bristol model 371466-01-6
- 2)     Basis for selection - (See Item E general description)

- 3) Input: 0-10 V = 350,000 ohms
- 4) Output: 18 - 30 Hz
- 5) Temp range 0 - 60 degrees C
- 6) Packaging is on 2-3" x 3" printed wiring cord which is inserted into a Bristol model 811 case.
- 7) Power requirements  $\pm 15$  Vdc

#### A-3.6.4 Frequency Shift Keyed (FSK) Transmitter

- 1) 2 each - Bristol Model CT-22
- 2) Basis for selection - (See Item E general description)
- 3) Transmission frequency range 365 to 3500 Hz stabilized to 2 Hz or  $\pm 0.1\%$  whichever is greater.
- 4) Output Impedance: 600 ohms
- 5) Temperature range: 0 to 60 degrees C
- 6) Power Requirements: 15 vdc @ 48 mA

#### A-3.6.5 Frequency Shift Keyed (FSK) Receiver

- 1) 2 each - Bristol 37122706-2
- 2) Input level 6-13 Volts @ 680 ohms
- 3) Output: Impedance less than .01 ohms, transient overshoot less than 0.5% of full scale, ripple 15 mV P-P with normal voice quality long
- 4) Temperature range: 0-60 degrees C
- 5) Power Requirements:  $\pm 15$  V @ mA and -15 V @ 15 mA
- 6) General: The option #4 is an adaption of a Bristol CEM Tone Telemetry System. The multiplexed data is transmitted real time from the remote sensing station to the central data processing station by use of voice quality telephone lines. All components will be packaged in Bristol cases located at the remote station and the central processing station. All units can be powered by a Bristol power supply which also mounts in the case. The case, Bristol model 811, is 6.87 H x 19 W x 13.53 deep and is designed to mount in a standard relay rack (19 in).

### A-3.6.6      Telephone Data Sets

The 602C data set would be used in this configuration on a private line system where the remote site data would be transmitted continuously to the computer facility during the daylight hours. One 602C would be located at the remote site while another 602C would be located at the computer facility. The 602C has the following specifications.

- |     |                             |   |
|-----|-----------------------------|---|
| 1)  | Type unit:                  | Transmitter-Receiver  |
| 2)  | Type transmission:          | Single channel analog - 0 to 900 hz   |
| 3)  | Interface:                  | EIA RS 357 (voltage) - 0 to +7 volts d.c.   |
| 4)  | Synchronization:            | Provided by a secondary channel sending a 60 hz signal  |
| 5)  | Line facility:              | Voice switched network (DDD)<br>2001 type channel - private line<br>alternate voice/data<br>3002 type channel - private line<br>data only |
| 6)  | Operation:                  | Half duplex - two-wire  |
| 7)  | Works with:                 | Data Sets 602C  |
| 8)  | Unattended answer           | Yes   |
| 9)  | Automatic dialing:          | Can be provided with an 801 automatic calling unit  |
| 10) | Reverse channel:            | Yes   |
| 11) | Telephone handset and dial: | Integrated into set housing.<br>Rotary or TOUCH-TONE dials available  |
| 12) | Remote testing:             | Yes   |
| 13) | Power:                      | 105 - 120 volts, AC, 25 watts, equipped with U-blade ground-type plug   |
| 14) | Size:                       | Width....14 3/4"<br>Depth....11"<br>Height... 5 5/8"  |

### A-3.7 ON SITE CALCULATOR/PRINTER

The block diagram of the on line calculator/printer technique is shown in Figure A.3-7. The major disadvantage is cost. The major advantages are a self contained unit and packaging. The basic components of this type of data management subsystem are presented below.

#### A-3.7.1 Signal Conditioners

##### A) Instrumentation Amplifier

- 1) 5 each - Hewlett Packard dual channel model 2471A
- 2) Basis of selection was compatibility of performance and packaging with the 3485A scanner.
- 3) Input:  $\pm 11$  V max gain switchable in steps of 1.10, 100 and 1000. Common mode rejection  $>120$  db @ gain = 1000
- 4) Output:  $\pm 10$  V max at 0 to 50 mA, Impedance 0.1 ohm, zero drift  $\pm 10$  V per day RTI:, or  $\pm 1$  mV RTO
- 5) Dimensions: 7.75 H x 1.25 W x 10.625 D inches
- 6) Temperature range: 0 to 55 degrees C
- 7) Power requirements: +30 V @ 50 mA, -30 V @ 50 mA, +15 V @ 60 mA, -15 V @ 60 mA

##### B) Combining Case W/Integral Power Supply

- 1) 1 - Hewlett Packard 12670A
- 2) Selected because of mechanical and electrical compatibility to amplifiers
- 3) Input: 115 VAC 60 Hz
- 4) Output:  $\pm 15$  V and  $\pm 30$  V as required by Amplifiers
- 5) Dimensions: Standard 19 inch relay rack x 10.5 inches high

##### C) Calibration Module

- 1) 1 each
- 2) The Calibration Circuit will upon command remove the input signal from the Instrumentation Amplifier and inject a signal equal to 10% or 100% of the full scale span. This will give a complete calibration-operation check of the entire data management subsystem exclusive of the sensors.

- 3) Input power will be supplied by long life mercury cell batteries which will be replaced annually.
- 4) The calibration module will be packaged via one channel slot in the power rack.

#### A-3.7.2 Scanner

- 1) 1 each 10 channel unit - Hewlett Packard model 3485A
- 2) Primary advantage is versatility in that data channels can be interrogated sequentially on a continuous basis, singly or randomly. This unit is a plug in module designed to be used in either H-P 3480A or 3480B DVM's or 2070A data logger.
- 3) Input:  $\pm 10.0$  V,  $Z_{in} > 10^7$  ohms
- 4) Output: 4 1/2 digits, + BCD (optional)
- 5) Scanning rate: Variable (in continuous mode) from 1 channel/sec to 1000 channels/sec
- 6) Effective common mode rejection, D.C.  $> 80$  db, noise  $< 3 \mu$  VPP.

#### A-3.7.3 Digital Voltmeter

The digital voltmeter in this configuration would be a Hewlett Packard model 3480B. This unit digitizes the analog signals received from the scanner.

#### A-3.7.4 Coupler Controller

The coupler controller in this configuration is a Hewlett Packard model 2570A. It is used to establish two way communication between instruments (DVM) and peripheral devices such as the calculator/printer.

#### A-3.7.5 Calculator/Printer

The calculator/printer in this configuration is the Hewlett Packard model 9830A. This unit can be programmed to provide an on site hardcopy in the desired format of solar radiation data being monitored.

### A-3.8 DIGITREND/7 TRACK DIGITAL RECORDING

The block diagram of the digitrend/7 track digital recording technique is shown in Figure A.3-8. The major disadvantages to this system are assembly and checkout. The major advantages are cost, packaging, and proven design. The basic components of this type of data management subsystem are presented below.

### A-3.8.1      "Digitrend"

Digitrend is the name of a multi-point data logger manufactured by Doric Scientific Corporation of San Diego, California. This unit includes all of the data logging functions of input termination, reference junction compensation, solid state multiplexing, A/D conversion and a built-in electronic timer to initiate periodic logging cycles for unattended operation with selective intervals. Also, included are digital displays and a strip printer to give a hardcopy printout. The model 210-20, which was chosen for this configuration, has the following specifications.

- 1)      Input capability - 10 channels, optional to 100 channel
- 2)      The input channels are terminated into a JFET multiplexer which has a point to point scatter of less than  $\pm 3.0 \mu V$ .
- 3)      The output is actually a ratio of input voltage to a precise reference voltage, therefore any errors in amplifier gain and associated R&C values will be cancelled since the same errors exist in both the measure and the reference signal.
- 4)      The signal conditioning portion utilizes the dual slope integration technique with an automatic zeroing feature which automatically re-zeroes the signal conditioners after each scan.
- 5)      The precision reference voltage, upon which essentially all measurement error is dependent, is held to a temperature stability of 0.0006% per degree C and long term stability to 100 PPM long term calibration stability is held to within 0.03% of reading for six months.
- 6)      Noise is minimized by use of an active filter with a rejection rate of 18 db per octave.
- 7)      Resolution = 0.01% f.s. ( $10 \mu V$  for 10 V f.s.)
- 8)      The printer prints out: The data channel, polarity, 5 digits of data (analog) and 2 digits of engineering units. Printouts are made at a rate of up to 2.0 per second.
- 9)      With the BDC output option the output is directly compatible with a digital tape recorder with DTL/TTL compatibility.
- 10)     Input: range 0-10 mV, Impedance 200 megohms minimum.
- 11)     Calibration stability:  $\pm 0.01\%$  f.s. for six months  
 $\pm 0.003\%$  of reading/degree C

- 12) Zero stability:  $\pm 2 \mu$  V/degree C.
- 13) Temperature range: 10 to 50 degrees C.
- 14) Weight: 40 pounds.
- 15) Power required: 115 VAC @ 60 watts
- 16) Size: 7" H x 19" W x 17.5" D

A-3.8.2 Timer Control Unit (See Paragraph A-3.1.3)

A-3.8.3 Digital Clock (See Paragraph A-3.2.4)

A-3.8.4 Tape Interface (See Paragraph A-3.4.6)

A-3.8.5 7 Track Incremental Magnetic Tape Recorder  
(See Paragraph A-3.2.7)

#### A-3.9 DIGITAL TELEMETRY TO COMPUTER FACILITY

The block diagram of the digital telemetry to computer facility technique is shown in Figure A.3-9. The major disadvantage to this technique is the dial-up phone line cost. The major advantages are cost, packaging, proven design.

A-3.9.1 "Digitrend" (See Paragraph A-3.8.1)

A-3.9.2 Timer Control Unit (See Paragraph A-3.1.3)

A-3.9.3 Digital Clock (See Paragraph A-3.2.4)

A-3.9.4 Tape Interface (See Paragraph A-3.4.6)

A-3.9.5 Magnetic Tape Data Terminal

This unit is a Teletype 4210 magnetic tape data terminal. The basic function of this data terminal would be to record the digital data during the daylight hours and play the data back to a data recording system during the night at high speed. The specifications for this terminal are as follows:

- |    |                         |  |
|----|-------------------------|--|
| 1) | On line speed:          | Up to 2400 wpm<br>(240 characters per second)<br>2400 baud |
| 2) | Code:                   | ASCII (7 information,<br>1 parity)                         |
| 3) | Method of transmission: | Serial, 10 unit code                                       |
| 4) | Interface:              | Conforms with EIA RS-232-B                                 |

- 5) Tape: 1/2" precision magnetic tape  
(approximately 100 feet in a  
3" x 3" x 1" cartridge)
- 6) Cartridge capacity: 150,000 characters
- 7) Recording: MRB (Modified Return to Bias),  
9 track (8 data, 1 clock),  
125 characters per inch
- 8) Environment: Operating: 40° to 110°F ambient,  
Humidity: 95% maximum
- 9) Power: Approximately 150 watts idle,  
and 180 watts operating  
115 VAC  $\pm 10\%$   
60Hz  $\pm 0.5$  Hz or 50 Hz  $\pm 0.5$  Hz
- 10) Maintenance Interval: Recommended cleaning of tape  
head is once a week. Preventive  
maintenance every six months.
- 11) Dimensions: 12" W x 30" H x 23" D
- 12) Weight: 97 pounds

#### A-3.9.6 Telephone Data Sets

The 202C data set would be used in this configuration on a dial up system. One 202C would interface with the magnetic tape data terminal at the remote site and another would interface with a data recording system which could be located at the central computer facility. The 202C has the following specifications:

- 1) Type unit: Transmitter-Receiver
- 2) Type Transmission: Bit serial
- 3) Interface: EIA RS 232 (voltage)
- 4) Bit rate: Up to 1200 bits/second on voice  
switched network (DDD) and up to  
1800 bits/second on Private line,  
non-synchronous (see line  
Facilities below)

- 5) Line facility: Voice switched message network (DDD)  
1200 BPS  
2001 type channel (no conditioning)-  
private line alternate voice/data 1000  
BPS  
3002 type channel (no conditioning) -  
private line data only 1000 BPS  
2001 type channel with C1 conditioning -  
private line alternate voice/data 1000  
BPS  
3002 type channel with C1 conditioning -  
private line data only 1400 BPS  
2001 type channel with C2 conditioning -  
private line alternate voice/data 1800  
BPS  
3002 type channel with C2 conditioning -  
private line data only 1800 BPS
- 6) Operation: Half duplex-two-wire  
Full duplex-four-wire
- 7) Works with: Data Sets 202A, 202C, 202D, 202E
- 8) Unattended  
answer: Yes
- 9) Automatic  
dialing: Can be provided with an 801-type  
automatic calling unit
- 10) Reverse  
channel: Yes, Sender and detector-maximum-  
keying rate 5 baud.
- 11) Telephone  
handset and  
dial: Integrated into data set housing,  
Rotary or TOUCH-TONE dials available  
(See Remarks)
- 12) Remote  
testing: Yes
- 13) Power: 105-120 volts, AC, 11 watts, equiped  
with U-blade ground-type plug
- 14) Size: Width ...11"  
Depth ...14 1/2"  
Height... 5 1/2"

#### A-3.9.7 Data Recording System

A model MDRS-9 data recording system manufactured by Mitron Systems Corporation of Beltsville, Maryland would be used in this configuration to automatically dial up each remote site and record the digital data transmitted. The MDRS-9 unit has the following specifications:

## SPECIFICATIONS

- 1) Recording Format  
Standard: 9 track, IBM 2400-Series Compatible  
Optional: 7 track, IBM 729-Series Compatible
- 2) Recording Density  
9 track: 800 bpi                      7 track: 800/556 bpi
- 3) Recording Rate  
10,000 characters/second (800 bpi)  
6,950 characters/second (556 bpi)
- 4) Tape Speed  
12.5 inches per second
- 5) Reel Size  
6 or 8 1/2 inches
- 6) Tape Width  
1/2 inch wide, 1.5 mil thick
- 7) Rewind Speed  
75 inches per second
- 8) Fast Forward Speed  
75 inches per second
- 9) Read after Write  
Standard
- 10) Electronics  
Solid state
- 11) Temperature  
40 to 110 degrees F
- 12) Power  
105-125 volts, 5 amperes maximum
- 13) Size  
Recorder: 13" H x 22" W x 22" D  
Console: 6" H x 22" W x 22" D  
Stand: 28" High

- |     |                     |                   |         |
|-----|---------------------|-------------------|---------|
| 14) | Weight              |                   |         |
|     | 130 pounds          |                   |         |
| 15) | Recorder Controls   |                   |         |
|     | Remote Forward      | Rewind Stop-Reset | Reverse |
| 16) | Recorder Indicators |                   |         |
|     | Power On            | File Protect      |         |
| 17) | Console Controls    |                   |         |
|     | Power On/Off        | Search            |         |
|     | Reset               | Transmit/Receive  |         |
|     | Stop                | Data Set/Local    |         |
|     | Start               | Rate              |         |
|     | Tape Mark           |                   |         |
| 18) | Console Indicators  |                   |         |
|     | Off Line            | Data              |         |
|     | File Ring           | EOM               |         |
|     | End Tape            | EOT               |         |
|     | Ready               | Record Counter    |         |
|     | B1                  | Aux Counter       |         |
|     | B2                  | Audible Signal    |         |
|     | Read/Write Error    | Line              |         |

#### A-3.10 WEATHER MEASURE DIGITAL DATA LOGGER

The block diagram shown in Figure A.3-10 presents the basic components of the Weather Measure Digital Data Logger. The model M731-M9 was chosen for this configuration.

The M731-M9 Digital Data Logger is a complete data recording system. It accepts a wide variety of analog (or digital) signals and records them in compatible format on magnetic tape. The latest developments in solid state integrated circuitry are utilized.

The M731-M9 Data Logger consists of a signal processing section and a recorder. The signal processing section contains a 20-channel multiplexer, analog to digital converter, time code generator, parity generator, and an output register.

There are three modes of operation: single channel (SC); single scan (SS); and continuous. In the "single scan" mode the logger makes one complete scan at a rate of one channel per second

and is then idle until the start of the next scan. The interval between scans is switch-selectable at 1, 2, 5, 10, 20, 30, or 60 minutes. The length of the scan is also switch-selectable in terms of the number of channels scanned before going into the idle mode. Each scan starts at channel number one and continues through the channel number set on the thumbwheel switch labelled "last channel."

In the "continuous" mode the logger scans all channels in sequence at the rate of one channel per second. "Continuous" scanning ceases only when the "stop" button is pushed. Other sampling rates of 1, 2, 5, and 10 channels per second (as illustrated) are also available as an option.

In either "single scan" or "continuous" modes time is recorded at the beginning of each scan.

The "single channel" mode is used to display (not record) the level of any channel's input.

The scanning is accomplished by high performance reed switches. These switches are designed to switch low level signals with a minimum of thermal offset due to switch contacts.

An integration type of analog to digital converter is used. The converter generates a BCD output of 12 bits plus sign. Its input impedance is greater than 100 megohms. The accuracy is 0.1%/°F of reading  $\pm 1$  millivolt at 70°F with a temperature coefficient of .005%/°F when operating over a temperature range +32°F to 140°F. Operating outside of these temperature limits is possible with reduced accuracy. The standard input voltage range is  $\pm$  one volt full scale. Other inputs can be provided for on special order.

#### Signal Processor Specifications

- o Data Input ..... Analog Differential Voltages
- o Input Voltage, Standard .....  $\pm 1$ V plus 1V overrange
- o No. of Channels ..... 20 analog channels plus 2 time words
- o Resolution ..... 1 mV
- o Sampling Rate ..... 1 channel per second others on special order
- o Data Display Type ..... NIXIE type
- o Data Display Content ..... Sign and 3 digits plus 1 "over-range" signal
- o Time Display ..... Days, hours, and minutes
- o Clock Accuracy .....  $\pm .02\%$ , 15 to 35°C
- o Record Length ..... Time plus 1 to 20 analog channels
- o Accuracy ..... 0.1% full scale  $\pm 1$  mV
- o Scan Interval ..... Selectable in increments of 1, 2, 5, 10, 20, 30 and 60 minutes

- o Ambient Temp. Range ..... +32°F to 140°F with a temperature coefficient of .005%/°F
- o Code Format, Magnetic ..... IBM BCD, 7-track, NRZI  
Tape

#### Magnetic Tape Deck Specifications

- o Reel Size ..... 8 1/2"
- o Tape Length ..... 1200 feet
- o Rewind Time ..... 3 minutes
- o Incremental Write Speed ..... 0 to 100 Char./Second
- o Density ..... 556 bpi
- o Inter-Record Gap Time ..... 475 msec, at 556 bpi
- o Reel Drive ..... Constant torque reel motor
- o Capstan Drive ..... Permanent magnet DC stepper motor
- o Tape ..... 1/2 inch wide, 1.5 mil thick
- o Local Controls ..... Power On/Off; Load; Ready;  
File Gap; Rewind

#### System Specifications

- o Power Requirements ..... 115V, 50/60 Hz
- o Operating Current:  
M731-M (Magnetic Tape) ..... Idle, 1.0A; maximum, 1.5A
- o Dimensions:  
M731-M ..... 24-1/8" h x 21" w x 15" d
- o Shipping Weight:  
M731-M ..... 160 lbs

## SECTION A-4

### FINAL TRADE OFF STUDY

#### A-4.0 SUMMARY

A final trade off study was performed in which off-the-shelf digital data logger systems were compared against the requirements listed in Table A.4-1. This study resulted in the choice of an Esterline Angus model D-2020 data logger system. This study also produced an alternate data logger system, that could record for five days, at approximately one half the cost of the Esterline Angus system. This data logger is manufactured by Metrodata Systems.

The major decision factors in selecting the data logger system in this trade off study were: 1) recording time, 2) cost, 3) proven system reliability, and 4) manner in which each system meets the data management subsystem specifications in Table A.4-1.

On May 1, 1973 letters were sent to sixty different data system vendors. Of these sixty inquiries, thirty responses were received of which only five were applicable. Metrodata Systems responded with two options, 9-track and cassette systems, which resulted in a total of six systems to evaluate. These six systems are listed in Table A-4.2 along with their relative cost, number of tracks on the magnetic tape used in the system, and the recording time based on fifteen hour days.

#### A-4.1 ESTERLINE ANGUS DATA LOGGER

##### A-4.1.1 General Description

The Esterline Angus, Model D-2020 data logger system is shown in Figure A.4-1. Basically, the instrument is a digital DC-millivolt measuring device that provides a visual digital display and a digital printed record of the measured values of up to 20 analog input signals. In addition, the unit also incorporates a real time, solid-state, 24-hour digital clock, the time of which can be both visually displayed and printed out.

The major functional elements that comprise the Model D-2020 are shown in the block diagram of Figure A.4-2.

The Model D-2020 design is achieved through the use of reliable, solid-state, integrated circuit logic. In implementing the solid-state design, virtually all of the circuit functions are structured on easily accessible plug-in printed circuits cards.

TABLE A.4-1

## DATA MANAGEMENT SUBSYSTEM SPECIFICATIONS

<u>Input</u>	<u>Number of Channels</u>	<u>Range</u>
	4	0 - 10 millivolts
	10	0 - 100 millivolts
<u>Output:</u>	<ol style="list-style-type: none"><li>1. 9-track incremental magnetic tape</li><li>2. DENSITY - 800 BPI</li><li>3. FORMAT - IBM BDC</li><li>4. TIME - DAY:HOURL:MINUTE/SCAN</li><li>5. DATA - From continuous scan</li><li>6. Interrecord gap - once per hour</li></ol>	
<u>Operation:</u>	<ol style="list-style-type: none"><li>1. Scan type - continuous</li><li>2. Scan rate - one sample per channel every ten seconds</li><li>3. Recording period - Maximum of 15 hours per day for 31 days</li></ol>	
<u>Requirements:</u>	<ol style="list-style-type: none"><li>1. Subsystem life - 5 years</li><li>2. AC power amplifier</li><li>3. Geographic location - Continental United States</li><li>4. Period of operation - Dawn to dusk</li><li>5. Calibration of Data Management Subsystem</li><li>6. Record data in a computer ready format</li><li>7. Record timing information for rapid computerized data reduction</li><li>8. Data retrieval period - once per month</li></ol>	

TABLE A.4-2

## DATA MANAGEMENT SUBSYSTEM - FINAL TRADE OFF SUMMARY

NUMBER	NAME	MODEL	COST	TRACKS	RECORDING TIME (15 HOUR DAY)
1	Esterline Angus	D-2020	\$14,234.	9	40
2	Weather Measure	M731-M9	16,726.	9	29
3	KAYE	8001	16,623.	9	11
4	Metrodata	DL620	13,506.	9	37
5	DATEL (Cassette to 9-track one time hardware cost)	LPS-16	7,225.*	2	1.7
6	Metrodata (Cassette to 9-track one time hardware cost)	DL620	9,411.* 7,094. 9,965.	4	5.2

\*Assembly required

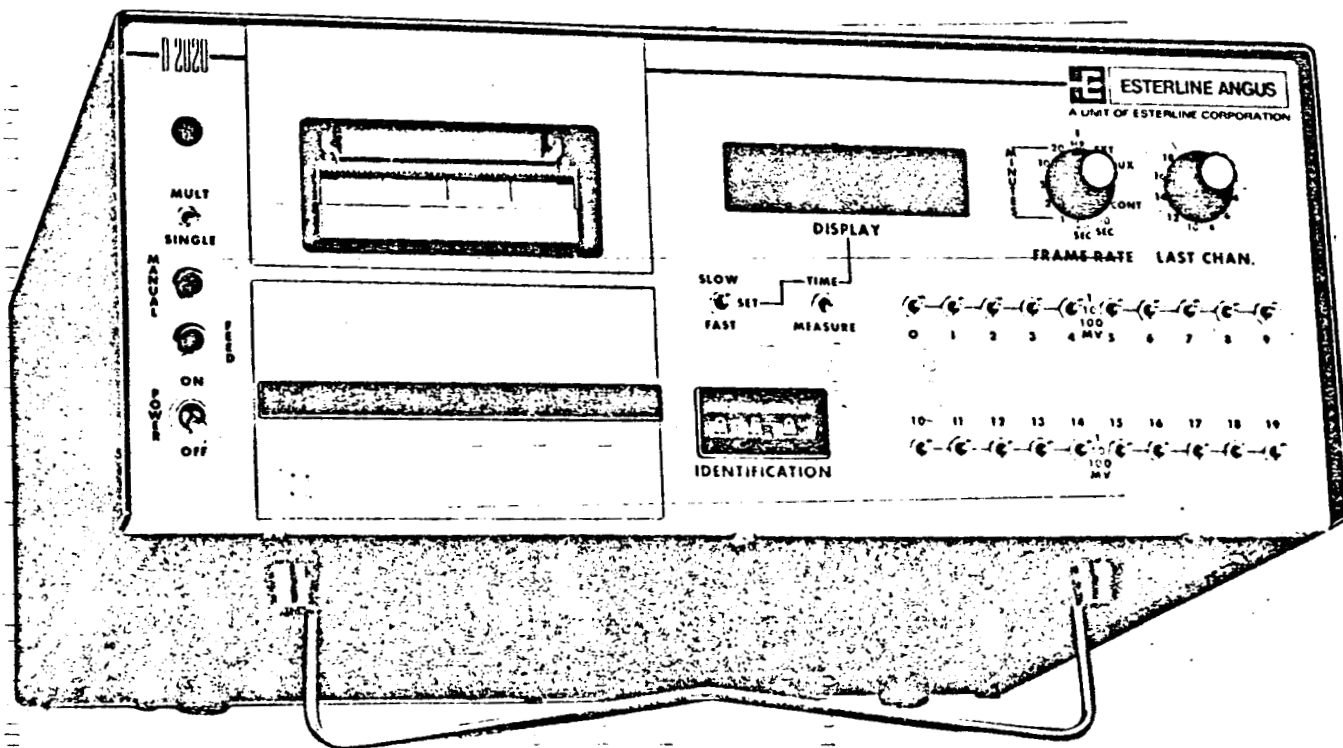


Figure A.4-1

Esterline Angus Model D-2020  
Digital Data Logger

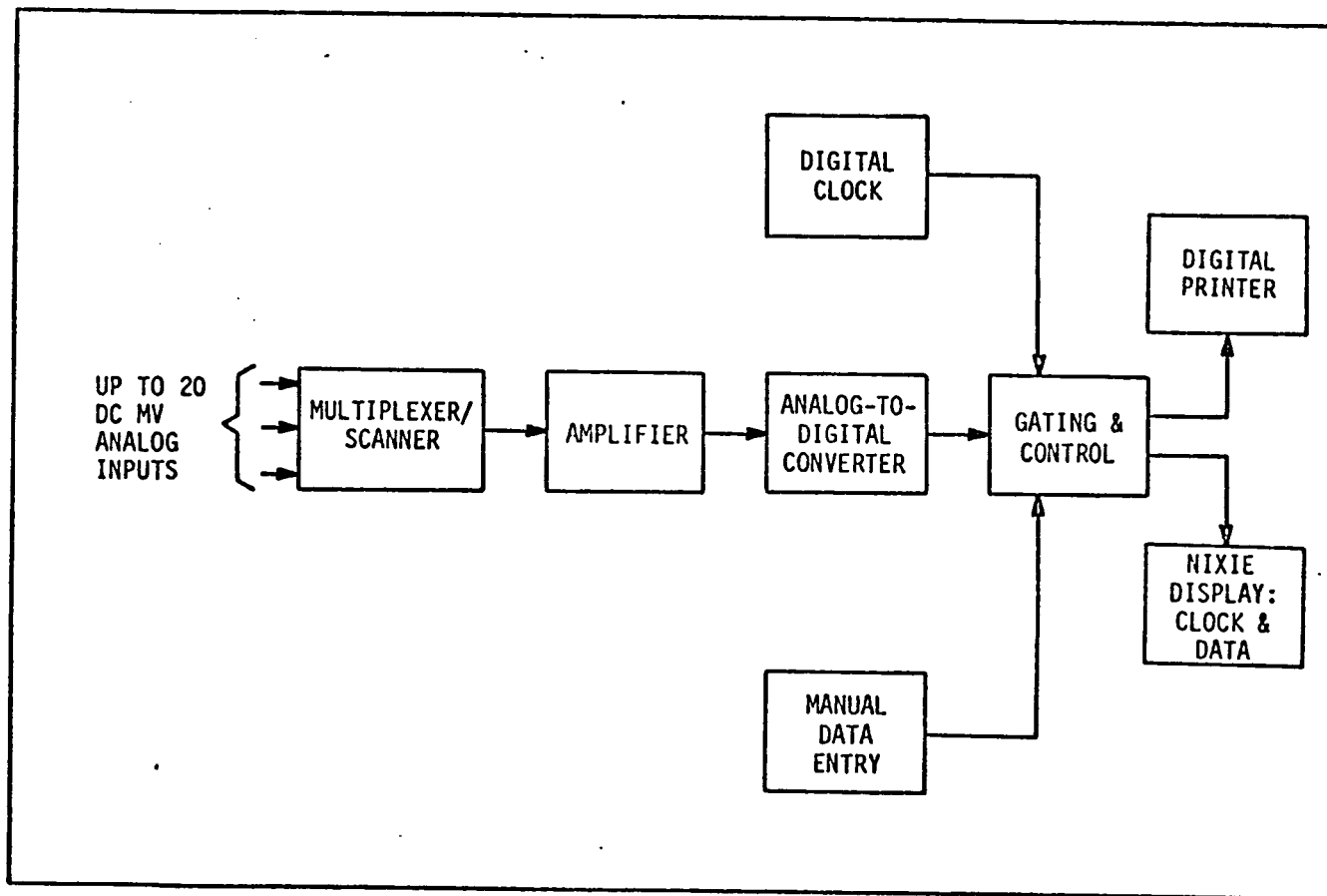


Figure A.4-2

Functional Elements of D-2020

Utilization of the printed circuit cards keeps maintenance requirements at a minimum. Suspected areas of circuit malfunctions may be quickly analyzed and repaired by directly substituting a card(s) in place of the faulty card(s) -- thereby eliminating the time consuming procedures of unsoldering and soldering individual circuit components on the cards.

#### A-4.1.2 System Components

The Esterline Angus Digital Data Logger System, which was configured to perform the data management function for the sunfall monitor, included the following hardware:

1. Low level span calibrations, 1mV/10mV/100mV DC.
2. Self contained real time clock, synchronized with line frequency of incoming AC power, with reading of 00:00 to 23:59 hours and minutes.
3. All front panel controls as described in standard literature will be provided, including end of frame selector switch, frame rate time selector switch, display readout selector, single/multiple scan selector, and print/print-record/record only selector switch.
4. ~~Included in this system is a specially adapted~~ magnetic tape recorder interface which will record only the essential data on the associated magnetic tape. This data will consist of the four numerical characters per channel, which make up the digitized data readout, and will record only the eight characters required on the frame header line to provide the day, hour, and minute reading from the D-2020's clock. This data shall all be recorded in EBCDIC code on the associated 9 Track, 800 BPI incremental magnetic tape recorder, Peripheral Equipment Corporation Model 2807-9, with 2400 foot tape reel.
5. Scaling networks to divide 0 - 240 millivolts and 0 - 8.0 volts sensor outputs to the 0 - 100 millivolt range for input to the D-2020 digital data logger.

6. Calibration circuit to provide 50 millivolts to an unused channel of the data logger. This signal will be recorded and then used by the software as a standard reference for determining if a multiplying factor should be used to correct sunfall data due to a malfunction in the data management subsystem.
7. Thermocouple reference junction to provide accurate readings from thermocouples used in the system.

#### A-4.1.3 System Specifications

##### Esterline Angus D-2020 Digital Data Logger:

- |    |                              |   |
|----|------------------------------|---|
| 1. | Number of Channels           | 20 (expansion capability to 200)  |
| 2. | Operational Modes            | 1. Automatic scan of any length frame determined by front-panel switches. (Frame scan interval variable from continuous to one scan per hour.)<br>2. Single or continuous scan of any one channel.<br>3. Local or external trigger for single channel or single frame scan. |
| 3. | Data Frame Interval Rate     | Variable from continuous to one frame per hour. External frame trigger available as standard.   |
| 4. | Data Frame Length            | Variable by "LAST CHAN." selector switch on front panel.  |
| 5. | Data Presentation            | 1. Visual data on 3 1/2 digit display with polarity indication and floating decimal point. May read either time or data.<br>2. Printed record on fan-fold paper from self-contained printer.  |
| 6. | Channel Scan Rate            | 2.5 channels per second.  |
| 7. | Data Frame Indication Number | Three digits controlled by front-panel manual entry switches. An option permits automatic advance of this number without visual display.  |

8. Clock Internal, digital, real time, solid state clock. Twenty-four hour time read out in hours and minutes. Clock is synchronous with line frequency, 50 Hz or 60 Hz.
9. Input Configuration Floating, differential 3-wire input (high, low and guard). Complete channel isolation (all three leads switched).
10. Amplifier Solid state chopper stabilized, differential with programmable gain.
11. Input Ranges Choice of three: 1, 10 and 100 MV DC individually selectable by front-panel switches. Readable over-range on all ranges is 200%.
12. Resolution 3,000: 1 overall resolution. 1 microvolt (on MV range).
13. Input Impedance 100 megohms all ranges
14. Source Impedance Maximum 10K ohms.
15. Noise, Referred to Input. 5 microvolts peak-to-peak
16. Common Mode Voltage 200 VDC and 120 VAC maximum.
17. Common Mode Rejection 120 db (1,000,000:1) at DC  
100 db (100,000:1) at 60 Hz AC.
18. System Accuracy  $\pm 0.1\%$  of reading, one digit, or 5 microvolts, whichever is greater,  $\pm$  one digit.
19. Operating Temperature Range  $0^{\circ}\text{C}$  to  $+60^{\circ}\text{C}$ .
20. Temperature Coefficient of Offset 0.2 microvolt per  $^{\circ}\text{C}$  referred to input
21. Temperature Coefficient of Gain. 0.1% of reading per  $15^{\circ}\text{C}$ .
22. Data Printout Twenty-column printed record which identifies time, channel number, data identification number, 3 1/2 data digits floating about a fixed decimal point.

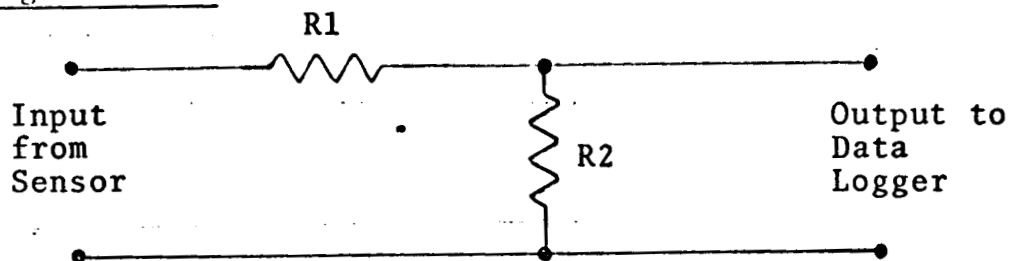
- |     |                   |   |
|-----|-------------------|---|
| 23. | Size              | 17" wide, 17 1/4" deep, 7" high.<br>(20-channel system).  |
| 24. | Weight            | Approximately 25 pounds.<br>(20-channel system).  |
| 25. | Power Requirement | 120 or 240 VAC. $\pm$ 10%, 50 and 60<br>Hz. Standby: 30 VA. Printing: 40<br>VA. (20-channel system).  |
| 26. | Output Options    | A. Paper tape interface. ASC II<br>(1968).<br>B. 7 or 9 track magnetic incremen-<br>tal tape interface, 556 or 800 BPI.<br>C. Teletype interface (no printer)<br>to ASR 33. |

Pertec 2807-9 Magnetic Tape Recorder:

- |     |                                     |  |
|-----|-------------------------------------|--|
| 1.  | Recording Mode                      | NRZI, IBM Compatible.  |
| 2.  | Recording Density                   | 800 CPI  |
| 3.  | Writing Step Rate                   | 700 Characters/Second  |
| 4.  | Reel Size                           | 10 1/2 inches, 2400 feet.  |
| 5.  | Character Transfer<br>Rate          | 0 to 1 KHz asynchronous.   |
| 6.  | Inter-Record Gap<br>Distance        | 0.6 inch   |
| 7.  | File Gap Distance                   | 3.8 inches   |
| 8.  | Tape Format                         | IBM compatible gaps and check<br>characters.                                 |
| 9.  | Tape Specifications                 | 0.5 inch (12.7 mm) wide, 1.5 mil<br>(38.1 microns) thick, Computer<br>grade. |
| 10. | Tape Tension                        | 8 ounces (226.7 grams).  |
| 11. | Rewind Speed                        | 50 ips (nominal) - 800 BPI.  |
| 12. | Inter-Channel<br>Displacement Error | 150 microinches (3.8 microns)<br>(max) at 800 cpi.                           |
| 13. | Power                               | 117/230 vac 48 to 400 Hz<br>250 watts - 10 1/2.                              |

- |     |                       |                               |
|-----|-----------------------|-------------------------------|
| 14. | Weight                | 85 lbs. (38.6 kg) for 10 1/2. |
| 15. | Mounting              | Standard EIA rack mount.      |
| 16. | Operating Temperature | 35° to 122°F (2° to 50°C).    |
| 17. | Relative Humidity     | 15 to 95% (non-condensing).   |
| 18. | Altitude              | 0 to 20,000 feet.             |

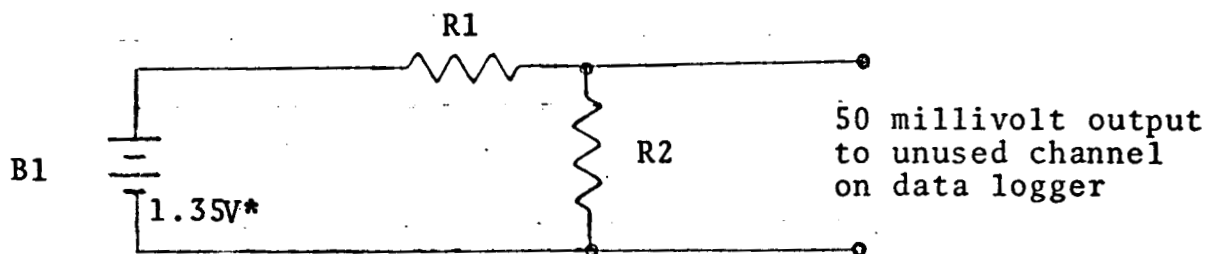
Scaling Networks:



Input Voltage	R1	R2	Output Voltage
0 - 240 mV	RN60D2431F	RN60D1001F	0 - 100 mV
0 - 8.0 V	RN60D8062F	RN60D1001F	0 - 100 mV

Mount components on Cinch Jones 12-140 terminal board. Mount terminal board on rear of data logger or thermocouple reference junction, whichever is most convenient.

Calibration Circuit:



Parts:

- B1 - Mallory RM 42R
- R1 - Resistor RN60D2742
- R2 - Resistor RN60D1001F
- H1 - Battery holder Cambion 2870
- TB1 - Terminal strip - Jones 10-140

\*Battery will be changed every 12 months.

### Hy-Cal 205-T Thermocouple Reference Junction:

1. Model 205-T
2. Reference temperature: 150°F
3. Stability:  $\pm 0.1^{\circ}\text{C}$ .
4. Ambient temperature  $\Delta$  (-30 to +120°F):  $\pm 0.25^{\circ}\text{F}$ .
5. Power: 115 VAC at 75 watts maximum.
6. Input termination: Screw terminals.
7. Output terminations: MS3102A connector.
8. Type T (ISA)
9. Channels: 26
10. Size: 5 1/4" H X 17" W X 9" D (rack mount).

#### A-4.1.4 System Cost

The prices stated here are based on the vendor quotations received at the time of inquiry and are provided only to show the relative cost of the Esterline Angus D-2020 Programmable Data Acquisition System.

\$ 4,764	D-2020 basic system
499	Low level span calibration
623	Magnetic tape interface
485	Character elimination
242	Day counter
208	End of record gap control
415	EBCDIC coding converter
6,579	Pertec 2807-9 magnetic tape recorder
17	Calibration circuit
402	Thermocouple reference junction
<hr/>	
\$14,234	

#### A-4.1.5 Total Recording Time Calculation

##### A. Characters per scan:

14	Channels for sunfall data
+1	Channel for calibration signal
<hr/>	
15	Channels of data per scan
x4	Characters per channel
<hr/>	
60	Characters of data per scan
+8	Characters per frame header per scan
<hr/>	
68	Characters per scan

B. Tape consumption per scan:

Recording density = 800 characters per inch

$$\frac{68 \text{ characters per scan}}{800 \text{ characters per inch}} = 0.085 \text{ inch per scan}$$

C. Record Length:

Record gap = 0.6 inches

Record time = 15 minutes

Scan rate = 8 scans per minute

$$\begin{array}{rcl} .085 & \text{inch per scan} & \\ \times 8 & \text{scans per minute} & \\ \hline .680 & \text{inch per minute} & \\ \times 15 & \text{minutes per record} & \\ \hline 3400 & & \\ 680 & & \\ \hline 10.200 & \text{inches per record} & \\ +0.6 & \text{inches per record gap} & \\ \hline 10.8 & \text{inches per record} & \end{array}$$

D. Recording Time for Tape:

Tape length = 2400 feet

$$\text{Number of records per hours} = \frac{60 \text{ minutes/hour}}{15 \text{ minutes/record}} = 4 \frac{\text{records}}{\text{hour}}$$

$$\begin{array}{rcl} 10.8 & \text{inches per record} & \\ \times 4 & \text{records per hour} & \\ \hline 43.2 & \text{inches per hour} & \end{array}$$

$$\frac{(2400 \text{ feet/tape}) (12 \text{ inches/foot})}{43.2 \text{ inches/hour}} = 666 \frac{\text{hours}}{\text{tape}}$$

Using a maximum of 15 hours per day operation of the sunfall monitor, the recording time in 15 hour days is:

$$\frac{666 \text{ hours/tape}}{15 \text{ hours/day}} = 44.4 \text{ days/tape}$$

Estimating some wasted tape for starting and stopping plus dimensional tolerances at 10% less than the above calculations:

$$\begin{array}{rcl} 44.4 & \text{days (per calculations)} & \\ -4.4 & \text{days (10\% estimated wasted tape)} & \\ \hline 40.0 & \text{days} & \end{array}$$

## A-4.2 Weather Measure Data Logger

### A-4.2.1 General Description

The M731-M9 Digital Data Logger, as shown in Figure A.4-3, is a complete data recording system. It accepts a wide variety of analog (or digital) signals and records them in computer compatible format on magnetic tape. The latest developments in solid state integrated circuitry are utilized.

The M731-M9 Data Logger consists of a signal processing section and a recorder. The signal processing section contains a 20-channel multiplexer, analog to digital converter, time code generator, parity generator, and an output register. This digital data logger is a complete link between sensors of many types and a computer.

There are three modes of operation: single channel (SC); single scan (SS); and continuous. In the "single scan" mode the logger makes one complete scan at a rate of one channel per second and is then idle until the start of the next scan. The interval between scans is switch-selectable at 1, 2, 5, 10, 30, or 60 minutes. The length of the scan is also switch-selectable in terms of the number of channels scanned before going into the idle mode. Each scan starts at channel number one and continues through the channel number set on the thumbwheel switch labelled "last channel".

In the "continuous" mode the logger scans all channels in sequence at the rate of one channel per second. "Continuous" scanning ceases only when the "stop" button is pushed. Other sampling rates are available upon request as an option. Switch selectable sampling rates of 1, 2, 5, and 10 channels per second are also available as an option.

In either "single scan" or "continuous" modes time is recorded at the beginning of each scan.

The "single channel" mode is used to display (not record) the level of any channel's input.

The scanning is accomplished by high performance reed switches. These switches are designed to switch low level signals with a minimum of thermal offset due to switch contacts.

An integration type of analog to digital converter is used. The converter generates a BCD output of 12 bits plus sign. Its input impedance is greater than 100 megohms. The accuracy is 0.1% of reading  $\pm 1$  millivolt at 70°F with a temperature coefficient of .005%/°F when operating over a temperature range +32°F to 140°F. Operating outside of these temperature limits is possible with reduced accuracy. The standard input voltage range is  $\pm$  one volt full scale. Other inputs can be provided for on special order.

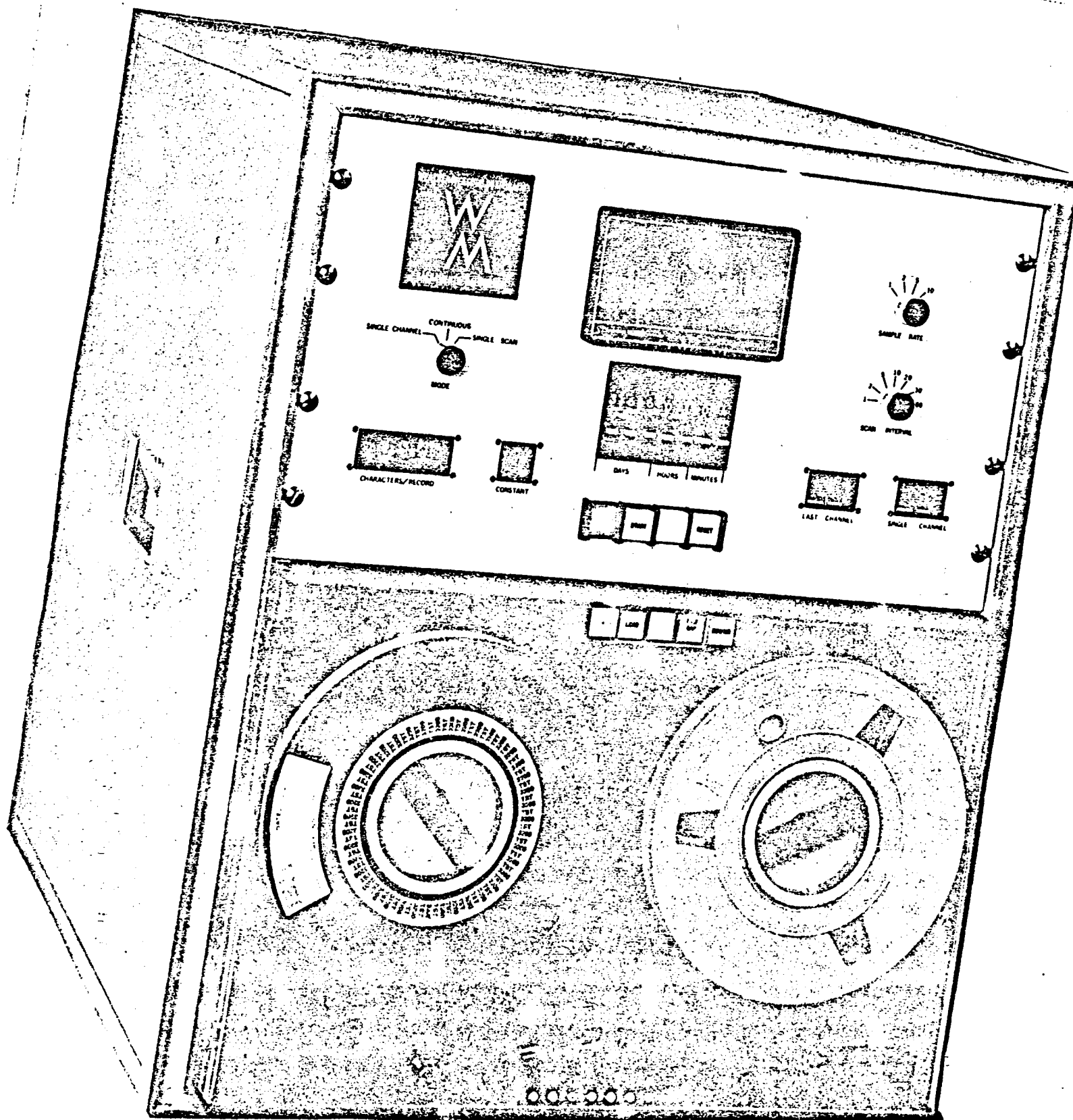


Figure A.4-3 Weather Measure M731-M9 Digital Data Logger

#### A-4.2.2 Systems Components

The Weather Measure System will consist of the following hardware:

1. M731-M9 Digital Data Logger with 9 track incremental magnetic tape recorder, 20 analog channels, plus three date and time channels.
2. Remote start/stop control circuit.
3. Low level input circuit.
4. Scaling networks to divide 0 - 240 millivolts and 0 - 8.0 volts sensor outputs to the 0 - 100 millivolt range for input to the M731-M9 digital data logger.
5. Calibration circuit to provide 50 millivolts to an unused channel of the data logger. This signal will be recorded and then used by the software as a standard reference for determining if a multiplying factor should be used to correct sunfall data due to a malfunction in the data management subsystem.
6. Thermocouple reference junction to provide accurate readings from thermocouples used in the system.

#### A-4.2.3 System Specifications

##### Signal Processor:

- o Data Input ..... Analog Differential Voltages
- o Input Voltage, Standard ..  $\pm 1V$  plus 1V overrange
- o No. of Channels ..... 20 analog channels plus 2 time words
- o Resolution ..... 1 mV
- o Sampling Rate ..... 1 Channel per second, others on special order
- o Data Display Type ..... NIXIE type
- o Data Display Content ..... Sign and 3 digits plus 1 "overrange" signal
- o Time Display ..... Days, hours, and minutes
- o Clock Type ..... Tuning Fork

- o Clock Accuracy .....  $\pm 0.2\%$ , 15 to 35°C.
- o Record Length ..... Time plus 1 to 20 analog channels
- o Accuracy ..... 0.1% full scale  $\pm 1$  mV
- o Scan Interval ..... Selectable in increments of  
1, 2, 5, 10, 20, 30 and 60 minutes
- o Ambient Temp. Range ..... +32°F to 140°F with a temperature  
coefficient of .005%/°F.
- o Code Format, Magnetic .... IBM BCD, 9-track, NRZI  
Tape

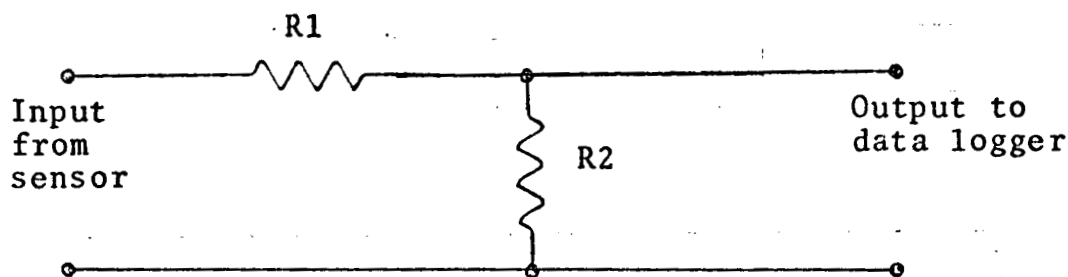
#### Magnetic Tape Deck:

- o Reel Size ..... 8 1/2"
- o Tape Length ..... 2400 feet
- o Rewind Time ..... 3 minutes
- o Incremental Write ..... 0 to 100  
Speed, Char./Second
- o Density ..... 556 bpi
- o Inter-Record Gap Time .... 475 msec. at 556 bpi
- o Reel Drive ..... Constant torque reel motor
- o Capstan Drive ..... Permanent magnet DC stepper motor
- o Tape ..... 1/2 inch wide, 1.5 mil thick
- o Local Controls ..... Power On/Off; Load; Ready;  
File Gap; Rewind

#### System:

- o Power Requirements ..... 115V, 50/60 Hz
- o Operating Current:  
M731-M (Magnetic Tape) .. Idle, 1.0A; maximum, 1.5A
- o Dimensions:  
M731-M ..... 24-1/8" h x 21" w x 17" d
- o Shipping Weight:  
M731-M ..... 160 lbs.

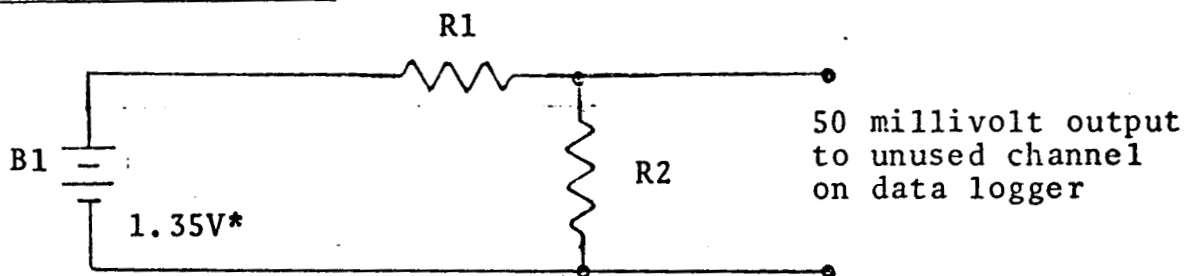
### Scaling Networks:



Input Voltage	R1	R2	Output Voltage
0 - 240 mV	RN60D2431F	RN60D1001F	0 - 100 mV
0 - 8.0 V	RN60D8062F	RN60D1001F	0 - 100 mV

Mount components on Cinch Jones 12-140 terminal board. Mount terminal board on rear of data logger or thermocouple reference junction, whichever is most convenient.

### Calibration Circuit:



### Parts:

- B1 - Mallory RM42R
- R1 - Resistor RN60D2742
- R2 - Resistor RN60D1001F
- H1 - Battery holder Cambion 2870
- TB1 - Terminal Strip - Jones 10-140

\*Battery will be changed every 12 months.

### Hy-Cal 205-T Thermocouple Reference Junction:

1. Model 205-T
2. Reference temperature: 150°F
3. Stability:  $\pm 0.1^{\circ}\text{C}$
4. Ambient temperature  $\Delta$  (-30 to +120°F):  $\pm 0.25^{\circ}\text{F}$
5. Power: 115 VAC at 75 watts maximum.
6. Input terminations: Screw terminals
7. Output terminations: MS3102A connector
8. Type T (ISA)
9. Channels: 26
10. Size: 5 1/4" H x 17" W x 9" D (rack mount)

#### A-4.2.4 System Cost

The prices stated here are based on the vendor quotations received at the time of inquiry and are provided only to show the relative cost of the Weather Measure M731-M9 Data Logging System.

\$15,477	M731-M9 Digital Data Logger
138	Remote start/stop control circuit
692	Low level input circuit
17	Calibration module
402	Thermocouple reference junction
<u>\$16,726</u>	

#### A-4.2.5 Total Recording Time Calculation

Weather Measure's product catalog number 772 states on page 168 that with a 1200 foot magnetic tape 60 - 24 hour days of recording twenty channels of data plus time can be accomplished with a scan interval of one minute and an interrecord gap every hour. In order to determine the total recording time for a scan interval of every ten seconds and a 2400 foot reel of magnetic tape, the following calculation was performed.

- A. Number of 24 hour-days of recording at a 10 second scan interval.

$$\frac{60 \text{ days recording per 1 minute scan interval}}{6-10 \text{ second scan intervals per minute}} = 10 \text{ days}$$

- B. Number of hours of recording per 2400 foot magnetic tape reel.

$$\begin{array}{r} 10 \text{ days per 1200 foot reel} \\ \times 24 \text{ hours per day} \\ \hline 240 \text{ hours per 1200 foot reel} \\ \times 2 \text{ 1200 foot reels per 2400 foot reel} \\ \hline 480 \text{ hours of recording per 2400 foot reel} \end{array}$$

- C. Number of 15 hour days of recording.

$$\frac{480 \text{ hours of recording}}{15 \text{ hours recording per day}} = 32 \text{ days}$$

- D. Less 10% due to various causes.

Duration approximately 29 days.

#### A-4.3 Kaye Data Logger

##### A-4.3.1 General Description

The Kaye System 8000 is shown in Figure A.4-4. In the Kaye 8000, emphasis has been placed on reliable operation with ambient conditions and common mode voltage levels typically found in industrial environments. The hermetically-sealed scanning units will operate safely at common mode voltages in excess of 400 volts while introducing less than  $\pm 1 \mu V$  of thermal error. A unique electronic reference matches both slope and curvature of the output of a thermocouple to give reference accuracy of  $\pm 0.1^\circ F$  over a wide range of ambient temperature.

Sensors connected to the System 8000 may be grounded or ungrounded. The use of three-wire, shielded analog circuits and a triple-shielded transformer in the analog power supply provide a fully guarded system with maximum isolation from line noise and a common mode rejection in excess of 140 db.

Analog voltages are converted to digital values by means of a dual-slope integrating DVM having a chopper-stabilized, low-level amplifier and a high-level A/D converter with automatic correction for zero offset. The full-scale value of standard voltage ranges is 20,000 counts, but the internal full-scale count is 200,000. Dividing the basic count by ten on standard voltage ranges eliminates small counting errors.

The greater number of internal counts and a new digital computing circuit, voltage-to-function converter, provide accuracy and flexibility in conversion of transducer outputs to corresponding values of engineering parameters. For example, thermocouple voltages are converted to temperature units with a conformity of  $\pm 1.0^\circ F$  to the 1971 revised National Bureau of Standards thermocouple tables over the entire normal range of the common thermocouple types. Any system may contain up to three independent conversion circuits simultaneously, and is field changeable to allow even greater flexibility.

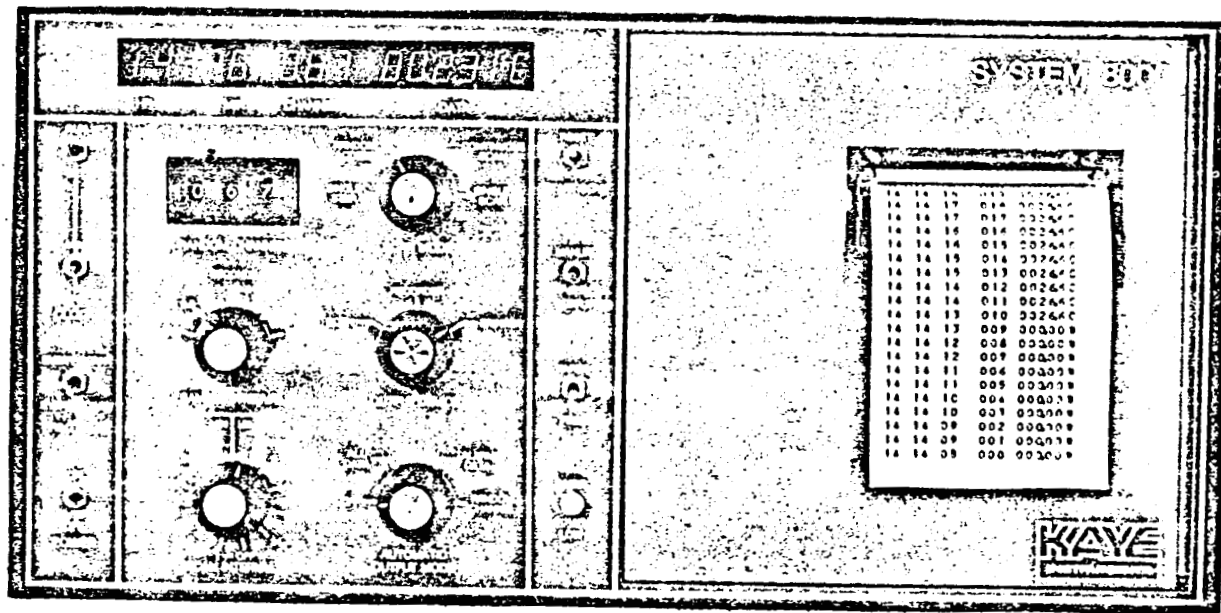


Figure A.4-4

Kaye System 8000 Digital Data Logger

All system controls are operated by easily accessible front-panel switches. The time, channel identification and data are displayed visually and may be recorded simultaneously on the built-in line printer or an optional serial recorder.

The modular approach of the System 8000 provides flexibility and expansion capability without burdening the basic system with the expense of features that are unnecessary in many applications.

#### A-4.3.2 System Components

The Kaye data logging system will consist of the following hardware:

1. Model 8001 Main Control Unit

The main control unit of the System 8000 includes all scanning and output controls, a 4 1/2 digit dual-slope integrating DVM, digital computing circuits to convert to voltage values of transducer outputs to corresponding engineering units, a digital clock providing time data and automatic system control, visual display of time, channel identification and data, and a twenty-one column line printer. Standard options include: serial output of data to a magnetic tape recorder, paper tape punch, teletype or other types of serial recorders, and external step and output control for remote.

2. Option 1D - Days Print Out

With option 1D days, hours and minutes will be recorded.

3. Option 3P - Magnetic Tape Interface

This option provides an 8 bit serial by character ASCII data output for the magnetic tape unit.

4. Model 8100 Scanning Module

The Model 8100 is a thirty-point, three-wire scanning module designed to accept up to three ten-channel Model 8200 input interface plug-ins. The scanning elements are completely immersed in oil within a hermetically sealed enclosure, guaranteeing ultimate reliability and extremely low thermal errors. A system may contain up to 33 Model 8100 modules.

5. Two-Model 8212 Voltage Plug-In 200 mV Interface

In addition to providing the input terminals for ten three-wire inputs, each Model 8200 plug-in automatically selects the proper voltage range in the DVM and activates the proper voltage-to-function conversion circuit within the main control unit.

6. Kennedy Model 8230C/Model 8109 Tape Recording System

The Kennedy model 8230C/Model 8109 is a fully coordinated system of magnetic tape units and formatting electronics designed for read/write operations in both NRZ1 and the newer 1600 CPI phase encoded tape formats.

7. Scaling networks to divide 0 - 240 millivolts and 0 - 8.0 volts sensor outputs to the 0 - 100 millivolt range for input to the 8000 digital data logger.

8. Calibration circuit to provide 50 millivolts to an unused channel of the data logger. This signal will be recorded and then used by the software as a standard reference for determining if a multiplying factor should be used to correct sunfall data due to a malfunction in the data management subsystem.

9. Thermocouple reference junction to provide accurate readings from thermocouples used in the system.

A-4.3.3 System Specifications

Kaye 8000 Series Digital Data Logger:

- |    |                       |   |
|----|-----------------------|---|
| 1. | Number of Channels    | 10 to 990 in 10 channel increments  |
| 3. | Maximum scan rate     | 3 readings/sec.   |
| 3. | Common mode voltage   | 400 VDC or AC   |
| 4. | Common mode rejection | 140 db at DC greater than 140 db above 50 Hz with 1000 ohm unbalance  |
| 5. | Normal mode rejection | 62 db at 59 Hz increasing 18 db per octave with infinite rejection every 10 Hz  |
| 6. | Resolution            | 1 $\mu$ v, 10 $\mu$ v, 0.1 mv, and 1 mv for full-scale voltage ranges of 20 mv, 200 mv, 2v, and 20v, respectively. 0.1°F or 0.1°C for all temperature ranges. |

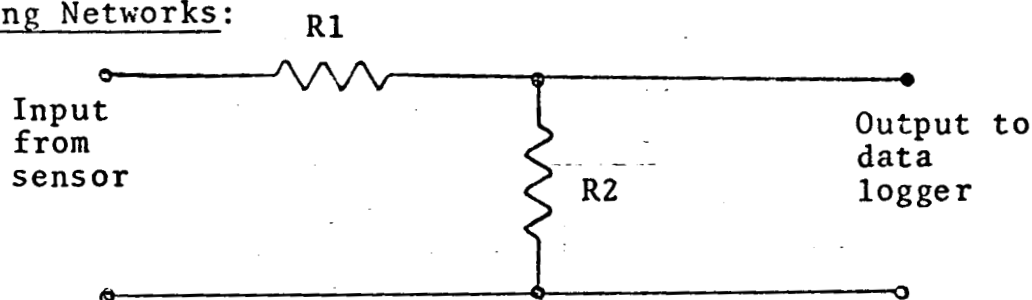
- |     |                                    |   |
|-----|------------------------------------|---|
| 7.  | Stability with time                | 30 days<br>±1 $\mu$ v±0.01% full scale ±0.01%<br>reading<br>1 year<br>±2 $\mu$ v±0.01% full scale ±0.02%<br>reading |
| 8.  | Stability with ambient temperature | Voltage Readings:<br>±0.2 $\mu$ v/°C±0.001% reading/°C.   |
| 9.  | Input impedance                    | Greater than 1000 megohms on thermocouple ranges and on 20 mv, 200 mv, and 2 v ranges.<br>1 megohm on 20 v range.   |
| 10. | Operating temperature              | 20°F to 110°F   |
| 11. | Power                              | 105 VAC to 125 VAC, 50/60 Hz.<br>220 VAC operation is optional.   |

Kennedy Model 8109 Magnetic Tape Unit:

- |     |                                 |  |
|-----|---------------------------------|--|
| 1.  | Data density                    | 800/1600   |
| 2.  | Tape tracks                     | 9  |
| 3.  | Tape Format                     | NRZ1/Phase-Encoded   |
| 4.  | Tape velocity (ips)             | 25 std.<br>10-37 1/2 avail.                                |
| 5.  | Speed variation                 | ±3% instantaneous<br>±1% long term                         |
| 6.  | Head type                       | Read-After-Write   |
| 7.  | Interchannel displacement error | 150 micro-inches max.<br>at 800 cpi                        |
| 8.  | Start/Stop time                 | 15 ms ±1 ms at 25 ips<br>(inversely proportional to speed) |
| 9.  | Gaps                            | Externally timed   |
| 10. | Parity                          | Externally generated                                       |
| 11. | Tape tension                    | 8 ±0.5 oz.   |
| 12. | Reel size                       | 10 1/2" (2400)   |
| 13. | Drive system                    | Single capstan 180° wrap                                   |
| 14. | Rewind speed (nominal)          | 150 ips  |
| 15. | Tape unit interface             | DTL, low-true  |

- |     |                           |  |
|-----|---------------------------|--|
| 16  | Size                      | 24.3" high<br>19" wide<br>11" deep                           |
| 17. | Weight                    | 90 lbs.  |
| 18. | Power                     | 115/230V (230 VAC optional)<br>±10%<br>48 - 500 Hz<br>350 VA |
| 19. | Ambient temperature range | +2 - +50°C   |
| 20. | Humidity (non-condensing) | 15 - 95% RH  |

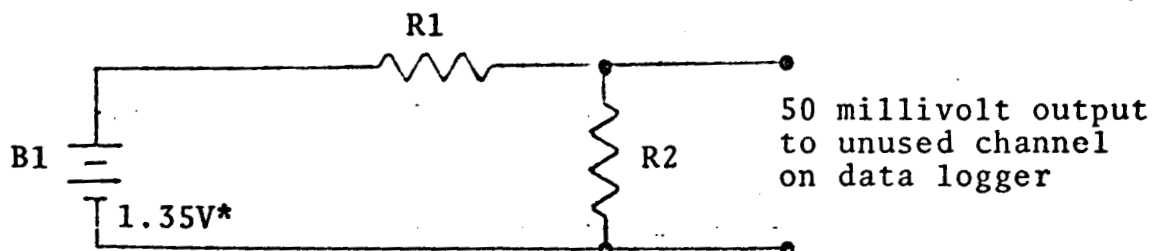
Scaling Networks:



Input Voltage	R1	R2	Output Voltage
0 - 240 mV	RN60D2431F	RN60D1001F	0 - 100 mV
0 - 8.0 V	RN60D8062F	RN60D1001F	0 - 100 mV

Mount components on Cinch Jones 12-140 terminal board. Mount terminal board on rear of data logger or thermocouple reference junction, whichever is most convenient.

Calibration Circuit:



Parts:

- B1 - Mallory RM42R
- R1 - Resistor RN60D2742
- R2 - Resistor RN60D1001F
- H1 - Battery holder Cambion 2870
- TB1 - Terminal strip - Jones 10 - 140

\*Battery will be changed every 12 months.

Hy-Cal 205-T Thermocouple Reference Junction:

1. Model 205-T
2. Reference temperature: 150°F
3. Stability:  $\pm 0.1^{\circ}\text{C}$
4. Ambient temperature  $\Delta$  (-30 to +120°F):  $\pm 0.25^{\circ}\text{F}$
5. Power: 115 VAC at 75 watts maximum
6. Input terminations: screw terminals
7. Output terminations: MS3102A connector
8. Type T (ISA)
9. Channels: 26
10. Size: 5 1/4" H x 17" w x 9" D (rack mount)

A-4.3.4 System Cost

The prices stated here are based on the vendor quotation received at the time of inquiry and are provided only to show the relative cost of the Kaye 8000 Digital Data Logging System.

\$ 5,263	Model 8001 Main Control Unit
346	Option 1D - Days Print Out
623	Option 3P - Magnetic Tape Interface
1,177	Model 8100 Thirty Point Scanning Module
277	Model 8212 Voltage Plug-In 200.0 mV
8,518	Kennedy Model 8230C/Model 8107
17	Calibration Module
402	Thermocouple Reference Junction
<u>\$16,623</u>	

#### A-4.3.5 Total Recording Time Calculations

Basis:

1. Record two channels of data per second
2. 20 channels per scan
3. Print time on channel 000 only
4. Record 15 hours per day

A channel of data in the 8000 system consists of:

- A. With time - 21 data characters plus "carriage return", "line feed", and "delete" = 24 characters.
- B. Without time - 11 data characters plus 3 control characters - 14 characters.

Therefore, a complete scan of 15 channels consist of 290 characters.

$$\begin{aligned} [1 \text{ scan} &= (1 \text{ channel} \times 24 \frac{\text{characters}}{\text{channel}}) \\ &= 290 \text{ characters} \\ &+ (19 \text{ channels} \times 14 \frac{\text{characters}}{\text{channel}}) \end{aligned}$$

Since one scan takes ten seconds, there will be 1740 characters per minute.

$$[(6 \text{ scans/minute}) \times (290 \text{ characters/scan}) = 1740 \text{ character/minute}]$$

Using 3,480 characters per block (2 minutes of recording) and recording at 800 characters per inch will require 4.35 inches of tape per block.

$$[(3480 \text{ characters/block}) \div (800 \text{ character/inch}) = 4.35 \frac{\text{inches}}{\text{block}}]$$

Adding an inter-record gap of 0.975 inches gives 5.325 inches/block or 0.44375 feet/block.

$$[(4.35 \text{ inches/block} + 0.975 \text{ inches/block}) \div (12 \text{ inches/foot}) = .44375 \text{ feet/block}]$$

Running at 30 blocks per hour ( $\frac{60 \text{ minutes}}{2 \text{ minutes/block}}$ ) and 15 hours per day produces 450 blocks per day or 199.6875 feet of tape/day

$$[(30 \text{ blocks/hour}) \times (15 \text{ hours per day}) \times (0.44375 \text{ feet/block}) = 199.6875 \text{ feet of tape/day}]$$

Using a 2400 foot reel of tape and recording approximately 200 feet of tape per day will provide 12 days of recording at a sample rate of two samples per second.

$[(2400 \text{ feet of tape}) \div (200 \text{ feet of tape/day}) = 12 \text{ days}]$

Less 10% due to various causes provides a duration of approximately 11 days.

#### A-4.4 Metrodata/9 Track Tape System

##### A-4.4.1 General Description

The Metrodata model DL620, as shown in Figure A.4-5, is a complete twenty-one channel data acquisition system which is capable of recording either analog or digital data. This unit utilizes front panel presettable Real Time Clocks, analog to digital converters and power supplies for the systems operation. A block diagram of this system is shown in Figure A.4-6.

Metrodata DL620 Data Logger solves the problems encountered with data acquisition and data reduction using strip charts and meters. Data can now be recorded in a computer compatible format even at remote sites. Reams of chart paper are eliminated; the man-hours associated with removing the data from the strip charts are eliminated; human errors in interpolation of data are eliminated. They have been eliminated by instantly scanning and digitizing the incoming analog data and recording them with the time of day on magnetic tape.

##### A-4.4.2 System Components

The Metrodata DL620 System using a 9 track recorder to perform the data management function for the sunfall monitor will include the following hardware:

1. DL620 data logger
  - A. DI500 digital interface card for a 1/2" computer-compatible magnetic tape unit.
  - B. A6A preamplifier cards
2. Cipher Tape Transport 100M - 360
3. Scaling networks to divide 0 - 240 millivolts and 0 - 8.0 volts sensor outputs to the 0 - 100 millivolt range for input to the DL620 digital data logger.
4. Calibration circuit to provide 50 millivolts to an unused channel of the data logger. This signal will be recorded and then used by the software as a standard reference for determining if a multiplying factor should be used to correct sunfall data due to a malfunction in the data management subsystem.

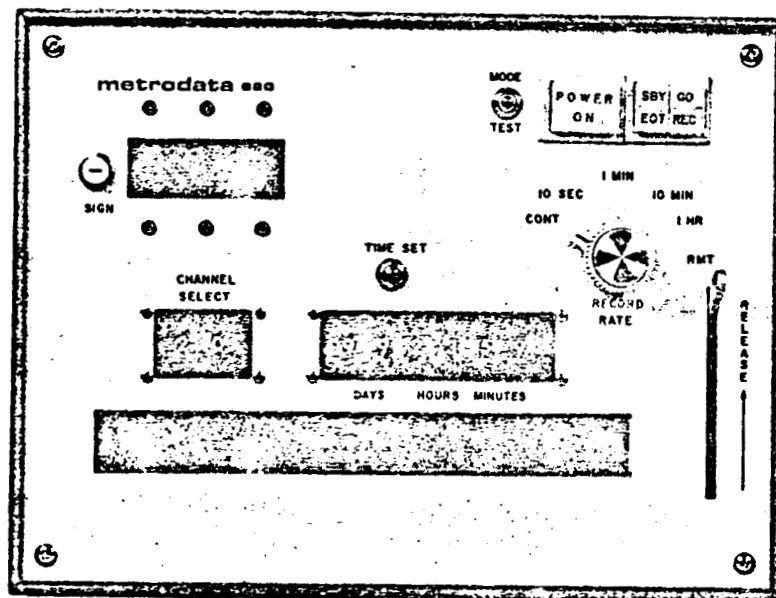


Figure A.4-5 Metrodata DL620 Modular Data Acquisition System

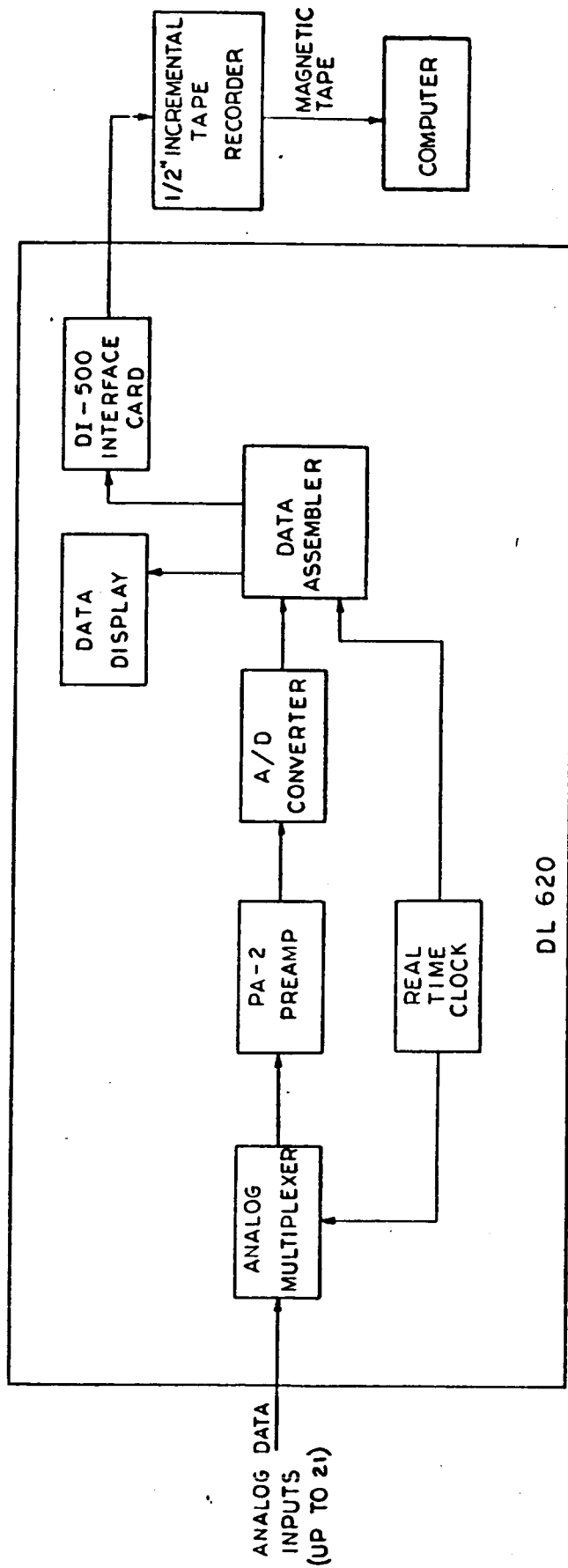


Figure A.4-6 Metrodata DL620/9 Track Tape System Block Diagram

5. Thermocouple reference junction to provide accurate readings from thermocouples used in the system.

A-4.4.3 System Specifications

Metrodata DL620 Data Logger:

- |     |                               |   |
|-----|-------------------------------|---|
| 1.  | Number of data channel        | 21 Analog - Standard<br>Expandable to 72 analog channels in increments of 24 using the accessory AX-10 analog expansion module        |
| 2.  | Input Characteristics Voltage | $\pm 10$ millivolts to $\pm 1$ volt full scale using the accessory PA-2 Preamplifier with 2 data channels per module.                 |
| 3.  | Impedance                     | 1 megohm - (Differential)<br>1 megohm each terminal to ground   |
| 4.  | Overvoltage limit             | $\pm 10$ volts DC (without preamp)  |
| 5.  | Resolution                    | 1 part in 1000 (0 to full scale)  |
| 6.  | Accuracy                      | $\pm 0.1\%$ $\pm 1/2$ L.S.B.<br>from $0^\circ$ to $40^\circ\text{C}$<br>$\pm 1.0\%$ $\pm 1/2$ L.S.B. when using the PA-2 preamplifier |
| 7.  | Conversion time               | 10 Milliseconds   |
| 8.  | Data scan rate                | (Selectable on order)   |
| 9.  | Internal clock                | Crystal controlled (1 MHz)<br>time base   |
|     | Accuracy                      | $\pm 2$ seconds/day   |
|     | Time record                   | Days, hours, minutes, seconds<br>from 000:00:00:00 to 365(366):<br>23:59:59 recorded each scan.                                       |
| 10. | Data display                  | 3 Digit NIXIE indicators display data from the switch selected channel  |
| 11. | Data polarity display         | Indicator lamp ON when data is negative   |

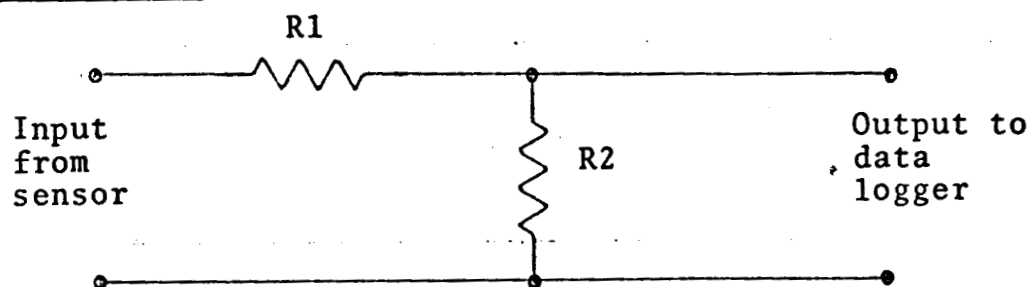
12.	Temperature range	0° to 40°C
13.	Humidity range	0% to 98% relative humidity, non-condensing
14.	Altitude range	0 to 30,000 feet
15.	Power input	117 VAC $\pm 10\%$ , 50-400 Hz, 35 watts which will be converted to 11.5 to 14 VDC, recording mode - 2.4 amps, standby mode - 160 m.a.
16.	Dimensions	11.0" wide x 8.3" high x 11.1" deep
17.	Weight	18 pounds

Cipher Tape Recorder 100M-360:

1.	Reel size	10 1/2"
2.	Tape length	2400'
3.	Rewind time	6 min
4.	Incremental wire	0-600 char./sec.
5.	Inter Record Gap Time	175 msec. (50 msec. optional)
6.	Density	9-track: 800 bpi
7.	Speed accuracy	$\pm 1\%$ long term, $\pm 3\%$ instantaneous
8.	Bit spacing accuracy (using internal optical encoder)	$\pm 2\%$ typical ( $\pm 4\%$ worst case)
9.	File gap time	250 msec.
10.	Reel Drive	Reel Servos
11.	Capstan drive	DC motor with velocity and position servo
12.	Tape	1/2" wide, 1.5 mil thick
13.	Format	IBM compatible, 9-track, NRZI
14.	Local Control & Indicators	Power On/Off, load, ready, file gap, rewind
15.	Power	115VAC 50-60 Hz

16.	Panel height	24 1/2"
17.	Width	19"
18.	Depth	12 1/4"
19.	Weight	80 lbs.

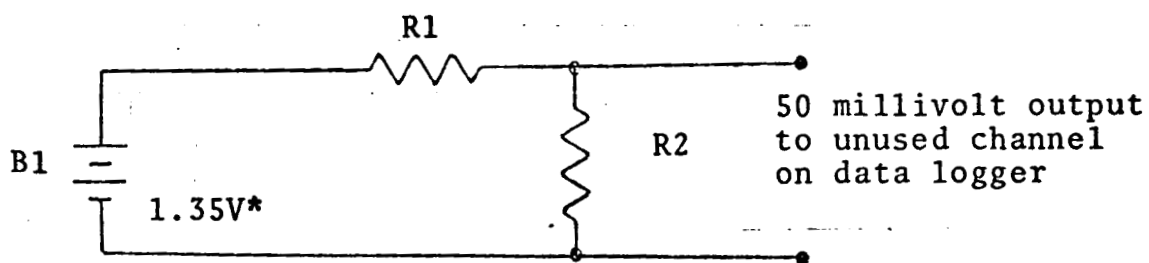
#### Scaling Networks:



Input Voltage	R1	R2	Output Voltage
0 - 240 mV	RN60D2431F	RN60D1001F	0 - 100 mV
0 - 8.0 V	RN60D8062F	RN60D1001F	0 - 100 mV

Mount components on Cinch Jones 12-140 terminal board. Mount terminal board on rear of data logger or thermocouple reference junction, whichever is most convenient.

#### Calibration Circuit:



#### Parts:

- B1 - Mallory RM42R
- R1 - Resistor RN60D2742
- R2 - Resistor RN60D1001F
- H1 - Battery holder Cambion 2870
- TB1 - Terminal strip - Jones 10-140

\*Battery will be changed every 12 months.

### Hy-Cal 205-T Thermocouple Reference Junction:

1. Model 205-T
2. Reference Temperature: 150°F
3. Stability:  $\pm 0.1^{\circ}\text{C}$
4. Ambient temperature  $\Delta$  (-30 to + 120°F):  $\pm 0.25^{\circ}\text{F}$
5. Power: 115 VAC at 75 watts maximum
6. Input terminations: screw terminals
7. Output terminations: MS3102A connector
8. Type T (ISA)
9. Channels: 26
10. Size: 5 1/4" H x 18" W x 9" D (rack mount)

#### A-4.4.4 System Cost

The prices stated here are based on the vendor quotations received at the time of inquiry and are provided only to show the relative cost of the Metrodata DL620/9-track Tape Digital Data Logger.

\$ 5,886	DL620 data logger
623	DI-500 digital interface
685	PA-2 preamplifier
76	RM-8 rack mount
5,817	Cipher 100M-360 tape recorder
17	Calibration circuit
402	Thermocouple reference junction
<u>\$13,506</u>	

#### A-4.4.5 Total Recording Time Calculation

Assumptions:

Data Density = 800 characters/inch.

Scan Length = (16 channels/scan) (4 character/channel)  
+ parity + preparity  
= 66 characters/scan

Record Length = (66 characters/scan) x (16 scans/record)  
= 1056 characters/record

## Computations:

1. The length of tape for one scan through 16 channels.

$$A. 1 \text{ scan} = \frac{66 \text{ characters/scan}}{800 \text{ characters/inch}} + \frac{.75 \text{ inch/record}}{16 \text{ scans/record}}$$

$$1 \text{ scan} = 0.0825 \text{ inch} + .0469 \text{ inch}$$
$$1 \text{ scan} = 0.1294 \text{ inch}$$

- B. This length will be consumed each 10 seconds while in the 10 second scan rate.

2. Duration of one tape is therefore:

$$\text{Duration} = 10 \text{ seconds/scan} \left[ \frac{2400 \text{ feet} \times 12 \text{ inches/foot}}{0.129 \text{ inches/scan}} \right]$$

$$\text{Duration} = 2,225,656 \text{ seconds}$$

$$\text{Duration} = 618.2 \text{ hours}$$

for a 15 hour recording day:

$$\text{Duration} = 41.2 \text{ days (15 hours/day)}$$

Less 10% due to various reasons,

Duration approximately 37 days (15 hours/day)

### A-4.5 Datel Data Logger

#### A-4.5.1 General Description

The Datel LPS-16 Digital Data Logger, as shown in Figure A.4-7, is a complete package for recording multi-channel analog data and single channel digital data. It features low power consumption and compactness making it especially suitable for remote data logging applications in unattended areas over long time periods. It will accommodate up to 16 channels of analog input and any number of 16 bit bytes of digital data in serial form. The analog data inputs can be sequentially or randomly multiplexed, converted into digital form, formatted and stored on a standard Phillips cassette. Approximately 120,000 samples of data along with identifying channel number can be stored on one cassette.

A functional block diagram of the system is shown in Figure A.4-8. The inputs required are up to 16 analog voltages, one digital input channel, control logic signals and power. The system can be conveniently divided into two subsystems; analog multiplexing and digitizing is one, and the digital recording is the other.

System LPS-16 utilizes C/MOS type logic throughout, thus negligible stand-by power is consumed. Only during the actual A/D conversion and storage on tape is any appreciable current consumed. Therefore, the LPS-16 may be operated for long periods on battery with low average power.

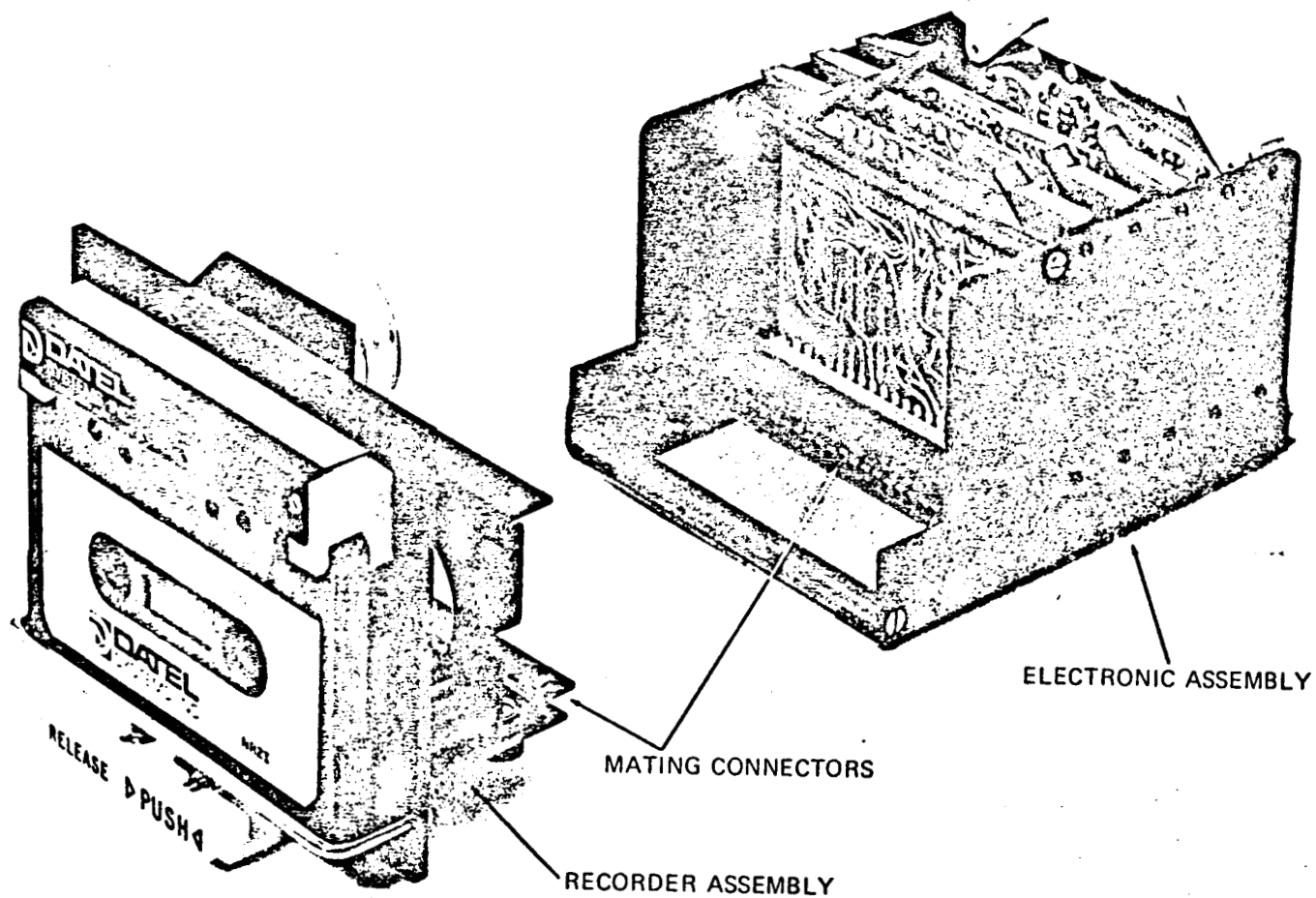


Figure A.4-7

Datel LPS-16 Digital Data Logger

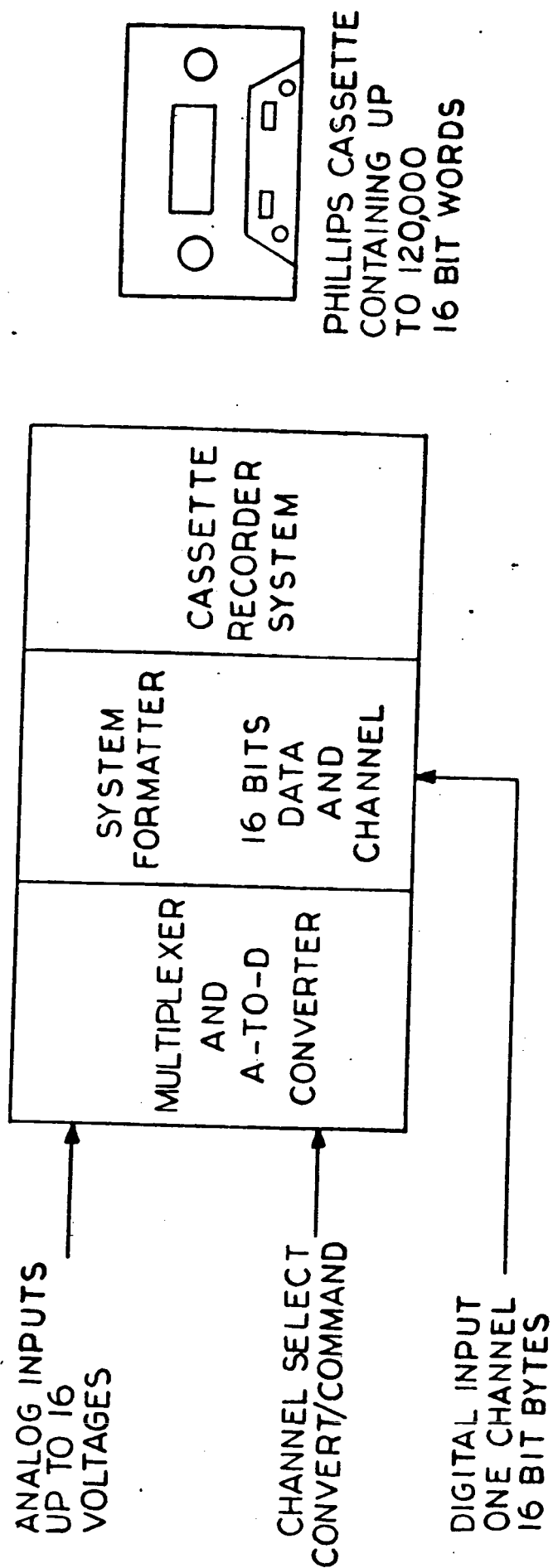


Figure A.4-8 Functional Block Diagram of Datel LPS 16 Data Logger

Cassette tapes prepared in the system may be read with the Datel Systems LPS-16R Reader system which provides a 16 bit parallel output of the data on tape at a rate of about 90 sixteen bit words per second. Each word consists of a 12 bit A/D value plus 4 bit channel address. This LPS-16R reader recognizes and stops on record gaps for convenient computer interface.

#### A-4.5.2 System Components

The Datel LPS-16 Digital Data Logger System will require the following hardware which will require assembly:

1. LPS-16-12B Datel Data Logger
2. Input signal conditioner
3. Control logic
4. Clock
5. 12V power supply
6. 5V power supply
7. Scaling networks to divide 0 - 240 millivolts and 0 - 8.0 volts sensor outputs to the 0 - 100 millivolt range for input to the LPS-16 digital data logger.
8. Calibration circuit to provide 50 millivolts to an unused channel of the data logger. This signal will be recorded and then used by the software as a standard reference for determining if a multiplying factor should be used to correct sunfall data due to a malfunction in the data management subsystem.

One time hardware required to produce a 9-track computer compatible tape includes:

1. LPS-16R cassette tape reader
2. Reader to 9-track tape interface
3. 9-track tape recorder.

### A-4.5.3 System Specifications

#### Datel LPS-16-12B Data Logger:

##### ANALOG INPUTS

Number of Analog Inputs	16
Input Channel Configuration	Single ended
Input Voltage Ranges	0V to -5VFS or $\pm 5VFS$
Channel Input Impedance	100 megohms "ON" or "OFF"
Channel Input Overload	$\pm 10V$ (max.)
Channel Mode of Operation	Random or Sequential
Channel Input Acquisition Time	100 $\mu$ sec - includes input settling time

##### SYSTEM PERFORMANCE

System Aperture Time	50 nsec
System Accuracy	$\pm 0.025\%$ of FS $\pm 1/2$ LSB
System Linearity	$\pm 1/2$ LSB
A/D Resolution	8, 10, 12 Binary Bits
System Temperature Coefficient	$\pm 0.004\%/^{\circ}C$
System Throughput Rate	200 msec per 16 bit word (12 bit A/D plus 4 bit channel address)
Input Channel Scan Rate	Up to 5 per second
A/D Digital Output Coding	Straight Binary - Unipolar Input Offset Binary or 2's complement - Bipolar Input
Cassette Tape Storage Method	Two channel NRZI: Track #1 - Data, Track #2 - Data (Complement)
Cassette Tape Format (2)	16 bit words (12 A/D bits plus 4 bits for channel address)
Cassette Tape Record Gap	Two bit gap separates each 16 bit word
Cassette Tape End-of-File Gap (3)	Sixteen bit file gap is recorded every 64th word

## SYSTEM CONTROL INPUTS (1)

Random Address Inputs	Selects analog channel, four lines 8-4-2-1-negative true logic
Random/Sequential Input	Selects multiplexer mode, one line - logic zero selects random mode
Device Select Input	Controls all input command lines, one line - negative true logic
Convert Input	Initiates A/D conversion, one line - negative true logic
Multiplexer Reset	Resets multiplexer to channel one, one line - negative true logic
Strobe Input	Strobes all input lines and internally stores them, one line - negative true logic
Auxiliary Serial Data in	Permits cassette recording of EXT. serial data in 16 bit bytes - one line
Data Select Input	Permits recording of either A/D output or EXT. serial digital data, one line - logic one selects A/D output
Start Two in	Initiates recording of external serial data, one line - triggers on negative going transition
Status	Positive during a recording cycle, one line - positive true logic
Load Forward	Advances cassette tape off leader to recording position, one line - negative true logic

## SYSTEM CONTROL OUTPUTS (1)

Frame Sync Output	Identifies channel one, one line - positive true logic
A/D Busy Output	Identifies A/D conversion in process, one line - positive true logic (during conv.)

Write Clock Output	When gated with file gap output, it provides shift signals for auxiliary data input, one line - positive true logic
File Gap Output	When gated with write clock output, it provides shift signals for auxiliary data input, one line - positive true logic
Power On Reset Output	Generates negative going pulse when system power is turned on, one line - negative true logic
Storage Media:	Standard Phillips certified data cassette 300 foot length
Storage Method	2 Channel NRZI
Number of Tracks	TWO: <u>Data</u> on track one Data complement on track two
Tape Format	16-bit words (12 A/D data bits and 4 channel address bits)
Record Gap	Two step record gap for every 16 bit word
File Gap	Sixteen-bit file gap every 64th word
Tape Storage Capacity	120,000 sixteen-bit words including gaps and load forward
Write Speed	90 steps per second 5 sixteen bit words per second (max.)
Data Input/Output	Serial NRZI
Motor	Single 1.5° angle stepper coupled to take-up reel by slip clutch mechanism
Motor Step Angle	1.5°
Angular Accuracy	±8 min. of arc non-accumulative
Tape Motion Control	Single capstan pinch roller drive. Head engages mechanically during write time
Tape Tension	0.4 oz. inches

Error Rate	1 bit in $10^7$
Type of Cassette Loading	Front
Recording Head	Dual channel single gap High quality digital type
Operating Mode	Write only

#### PHYSICAL ENVIRONMENTAL SPECIFICATIONS

Input Requirements	+ 12VDC $\pm 8\%$ 80ma when recording (960 mw) 10 $\mu$ a during standby (120 $\mu$ w) NOTE: Includes tape transport plus all electronics
Operating Temperature Range	-10°C to +60°C
Storage Temperature Range	-35°C to 70°C
Relative Humidity	10% to 95% w/o condensation
Shock & Vibration	1.0G @ 0-50 cps, all 3 axes
Physical Size W/Electronics (includes electronics)	4" high x 4 1/2" wide x 7 1/2" deep (6 1/2" deep behind panel)
Electronics	Contained on four plug-in PC cards mounted on a removeable PC mother board
Weight	2 lbs. includes recorder and electronics
I/O Mating Connectors	Cinch-part #251-22-30-160 - (I/O command signals) Elco-part #00-8218-24-722-005- (16 channel analog inputs, located on top rear of mux/S&H card)

- NOTES:
- (1) All input/output control signals are at standard C/MOS logic levels, Logic zero - 0V to +3V, Logic one - +9V to +12V
  - (2) Jumper connections can be made on the formatter card allowing selection of either 12 or 16 bit words. For example an 8 bit A/D converter with 16 analog channels would require only a 12 bit word length.
  - (3) Jumper connections can be made on the formatter card allowing for file gaps every 16, 32, or 64 words.

- (4) The LPS-16 data logger is shipped completely assembled and ready to operate. It is only necessary to connect the analog input signals, control signals, and 12 VDC power source plus inserting a cassette to begin recording.
- (5) An extremely important factor in the reliability of the LPS-16 data logging system is the cassette itself. Only a properly certified tape cassette should be used. The mechanical tolerances of the cassette cartridge and tape tension are also significant factors in the reliability of operation of the LPS-16 system. The preferred tape cassette is Datel Systems Type-TC-1.

#### Instrumentation Amplifier:

1. 8 Each Burr Brown Model 3088-16
2. Basis of selection: Performance - good common mode rejection. Adjustable gain, good temperature/drift stability; efficiently packaged, priced below most competitive amplifiers which usually have a higher slew rate and higher frequency response which is unimportant for this application.
3. Input Z:  $5 \times 10^{11} \Omega$  (gain 1 to 1100 variables)
4. Output:  $\pm 10 \text{ Vdc}$  (noise 6 mv rms @  $\beta = 1100$ ,  $30 \mu \text{V}$  @  $\beta = 1$ )
5. Dimensions: 3.5" H x 1.063" W x 7.03" D
6. Temp. range: 0 to  $60^\circ \text{C}$
7. Power requirements:  $\pm 15 \text{ VDC}$  @  $\pm 35 \text{ ma}$

#### Powered Rack Adapter:

1. 1 Each Burr Brown - Model 500/16
2. The rack will accommodate 10 of the 3088/16 amplifiers and supply necessary power and interface connections for the amplifiers.
3. Input: 105 - 125 V rms @ 50 to 400 Hz.
4. Output Voltage:  $\pm 15 \text{ Vdc}$  @ 100 ma reg. to  $\pm 0.1\%$ .
5. Rack is standard 19" instrument rack x 3.5" high x approximately 12" deep.
6. Temp. Range:  $-25^\circ \text{C}$  to  $+70^\circ \text{C}$ .
7. Weight of rack and 10 amplifiers approximately 25 pounds.

### Control Logic:

The necessary input control logic will be designed into the Electrical Power Control Subsystem to provide for remote operation.

### Anadex Clock:

Model: CK-610

### Reference:

This clock is supplied with the time reference derived from the 60 Hz (or 50 Hz) power line frequency. A 1 MHz crystal controlled reference is offered as an option.

### BCD Output:

DTL/TTL positive true 1, 2, 4, 8 BCD parallel output is provided.

Logic "1" = +2.4 V to +5.V maximum unloaded.

Logic "0" - +0.4 VDC maximum with sink current capacity of 6 MA maximum.

### Output Signals:

The following DTL/TTL compatible output signals are provided:

- a) 1 PPS
- b) 1 Pulse every 10 seconds
- c) 1 Pulse every minute
- d) 1 Pulse every hour
- e) 1 Pulse every 12 hours

### Power Input:

All standard models are capable of functioning from 115/230 VRMS, 60 Hz (or 50 Hz). Those models including the 1 MHz crystal option, will operate with a power line frequency of 50 to 400 Hz.

### Rear Controls and Connections:

On/Off power switch is mounted on the rear of the instrument.

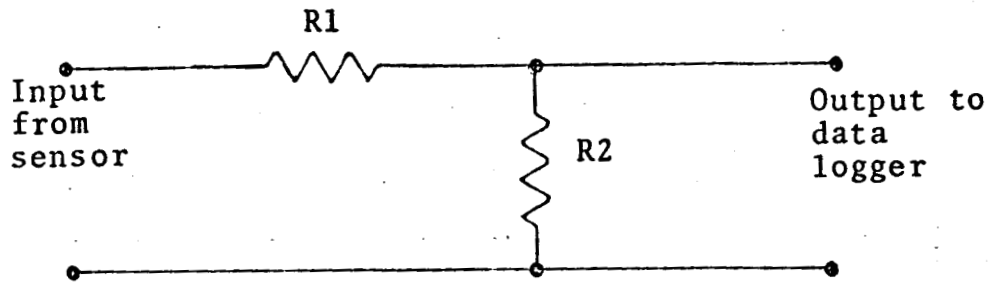
A fuseholder and the mating connector for the detachable power cord are mounted on the rear of the instrument.

A single connector provides access to the BCD output and to the various interface signals.

### Enclosure:

The instrument is mounted on a "graphic panel" measuring 4.5" H x 9.5" W. Dimensions behind the front panel are 3.5" H x 8.5" W x 15.2" D.

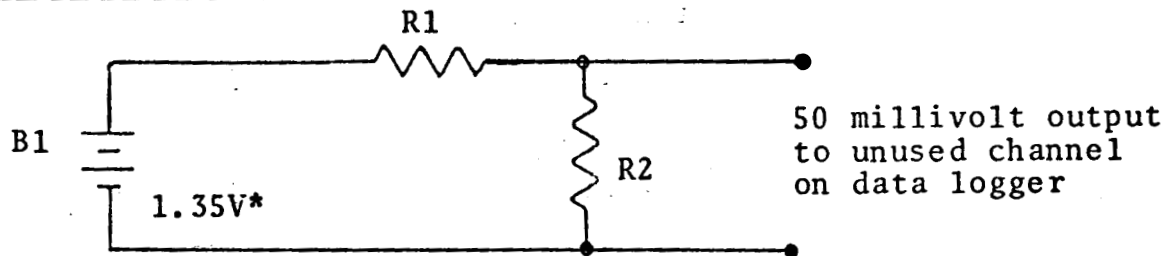
### Scaling Networks:



Input Voltage	R1	R2	Output Voltage
0 - 240 mV	RN60D2431F	RN60D1001F	0 - 100 mV
0 - 8.0 V	RN60D8062F	RN60D1001F	0 - 100 mV

Mount components on Cinch Jones 12-140 terminal board. Mount terminal board on rear of data logger or thermocouple reference junction, whichever is most convenient.

### Calibration Circuit:



### Parts:

- B1 - Mallory RM42R
- R1 - Resistor RN60D2742
- R2 - Resistor RN60D1001F
- H1 - Battery holder Cambion 2870
- TB1 - Terminal strip - Jones 10-140

\*Battery will be changed every 12 months.

### LPS-16R Reader:

- |    |              |                       |
|----|--------------|-----------------------|
| 1. | Data Input:  | Serial NRZI           |
| 2. | Data Output: | 16 Parallel Data Bits |
| 3. | Dimensions:  | 6" H x 17" W x 9" D   |
| 4. | Power:       | 115 VAC               |

### Reader to 9 Track Tape Interface:

The required interface unit will have to be designed and built to transfer the digital data from the reader to the 9 track tape unit.

### Kennedy 9 Track Tape Recorder:

- |                |                                   |  |
|----------------|-----------------------------------|--|
| 1.             | Model 1610/360                    |  |
| 2.             | Write Rate:                       | 0-500 Characters/second  |
| 3.             | Density:                          | 800 BPI $\pm 3\%$  |
| 4.             | Inter-Channel Displacement Error: | 800 BPI - $\pm 150$ microinches  |
| 5.             | Tape Format:                      | 9-Track, IBM compatible NRZI   |
| 6.             | Reel Size:                        | 10 1/2 inches,<br>1/2-inch standard computer<br>tape 1.5 mil   |
| 7.             | Rewind Time:                      | Less than 3 minutes  |
| 8.             | Tape Tension:                     | 2 ounces   |
| GAPS AND MARKS |                                   |  |
| 9.             | Inter-Record Gap:                 | 3/4 inch IRG automatically<br>generated upon external command.<br>IRG time is less than 550 ms<br>at 800 BPI.          |
| 10.            | File Gap:                         | Standard 3 1/2-inch file gap<br>automatically generated upon<br>external command or by front<br>panel pushbutton.      |
| 11.            | File Mark:                        | Standard binary 15 File Mark<br>written at conclusion of file<br>gap. File Mark is followed<br>by 3/4 inch Record Gap. |

- 12. Beginning of Tape Gap: In loading operation, BOT marker is sensed and 1/2 inch gap is automatically inserted.
- 13. Vertical Parity: Internally generated and recorded in track C. Odd or even parity is selected by external level.
- 14. Longitudinal Parity: Internally generated. LCC is written properly spaced from end of record.

#### FRONT PANEL CONTROLS

- 15. Load Forward: Automatically advances tape to load point and inserts BOT. After load operation, pressing this button causes tape to be advanced at 1000 steps per second.
- 16. Power: ON/OFF
- 17. Ready: Indicates that machine is ready to accept data. Machine achieves Ready status upon passing Load Point marker. If READY button and LOAD FORWARD button are pressed simultaneously, Ready status is achieved without marker.
- 18. File Gap: Pressing this button causes a file gap to be inserted.
- 19. Rewind: Initiates rewind motion. Rewind cannot be stopped until Load Point marker is reached, whereupon stop is automatic.
- 20. Remote Controls: All controls are brought out for remote operation.

#### INTERFACE REQUIREMENTS

- 21. Inputs: Standard interface is DTL compatible with current sinking positive logic having a "one" level of +4V to +6V and a "zero" level of 0V  $\pm$  0.5V functions, except remote controls which require closures to ground, are initiated by "one" levels. "zero" levels should be capable of sinking 5 ma.

22. Outputs: Outputs generated have "one" levels of +5V ±1V with a source impedance of 3K. Outputs will sink at least 10 ma. These lines may be modified to +10V by removing internal clamps.
23. Power: 115/230VAC, 50/60 HZ,, 150 VA

#### PHYSICAL REQUIREMENTS

24. Size: 19" wide x 24 1/2" high x 10" deep
25. Mounting: Standard Retma Rack
26. Weight: 70 lbs.
27. Finish: Charcoal Gray  
FED STD 595-26440

#### ENVIRONMENTAL

28. Temperature: Operating: 0°C to 50°C  
Non-Operating: -10°C to 65°C
29. Humidity: 15% to 95% non-condensing
30. Altitude: Operating: 20,000 ft.  
Non-Operating: 40,000 ft.

#### A-4.5.4 System Cost

The prices stated here are based on the vendor quotations received at the time of inquiry and are provided only to show the relative cost of the Datal LPS-16 Digital Data Logger System:

\$2,209	LPS-16-12B data logger
2,715	Instrumentation amplifier
1,039	Control logic
969	Clock
138	12 Volt power supply
138	5 Volt power supply
17	Calibration circuit
<u>\$7,225</u>	

#### One time hardware cost:

\$1,932	LPS-16R reader
693	Reader to 9 track interface
6,786	9 track tape recorder
<u>\$9,411</u>	

#### A-4.5.5 Total Recording Time Calculations

Number of bits per scan:

$$[(15 \text{ inputs}) \times (12 \text{ bits/input}) + 12 \text{ bits for time}] \\ = 192 \text{ bits/scan}$$

Number of scans per tape:

$$[(2,000,000 \text{ bits/tape}) \div (192 \text{ bits/scan})] = 10,416 \text{ scans/tape}$$

Number of hours per tape:

$$[(10,416 \text{ scans/tape}) \times (10 \text{ seconds/scan})] = 104,160 \text{ seconds/tape}$$

$$[(104,160 \text{ seconds/tape}) \div (3600 \text{ seconds/hour})] = 28.9 \text{ hours}$$

Subtract interrecord gap time to establish recording time:

$$[28.9 \text{ hours} - 1.9 \text{ hours for IRG}] = 27 \text{ hours}$$

Number of 15 hour days:

$$[(27 \text{ hours}) \div (15 \text{ hours/day})] = 1.8 \text{ days.}$$

Less 10% due to various reasons,

Duration approximately 1.7 days (15 hours/day)

#### A-4.6 Metrodata/Cassette Tape System

##### A-4.6.1 General Description

The Metrodata model DL620/Cassette Tape Digital Data Logger System, as shown in Figure A.4-9, is a complete twenty-one channel data acquisition system which is capable of recording either analog or digital data. This unit utilizes front panel presettable Real Time Clocks, analog to digital converters and power supplies for the system operation. A block diagram of this system is shown in Figure A.4-10.

Metrodata's DL620 Data Acquisition System solves the problems encountered with data acquisition and data reduction using strip charts and meters. Data can be recorded in a computer compatible format even at remote sites. Playback of the data, using Metrodata's TR-625 Tape Reader, permits visual display of the digitized data and direct computer entry for processing. Reams of chart paper are eliminated; the man-hours associated with removing the data from the strip charts are eliminated; human errors in interpolation of data are eliminated. They have been eliminated by instantly scanning and digitizing the incoming analog data and recording them with the time of day on magnetic tape.

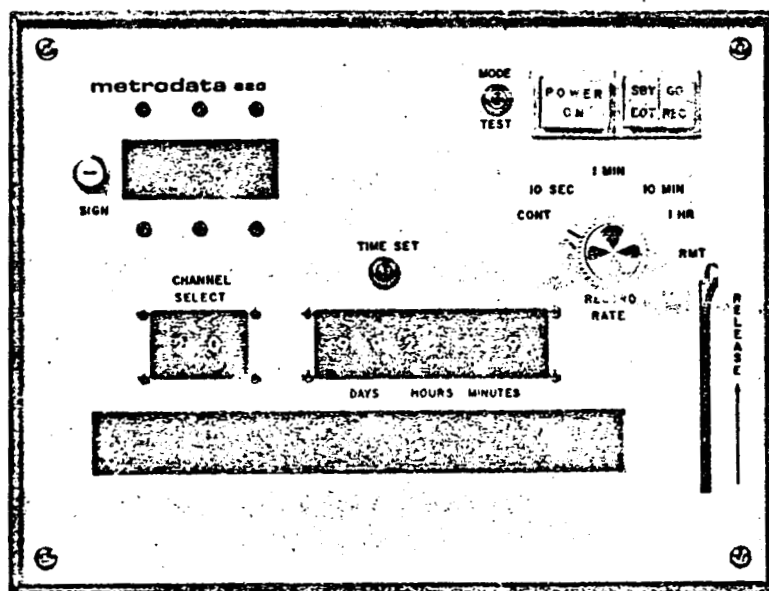


Figure A.4-9 Metrodata DL620 Modular Data Acquisition System

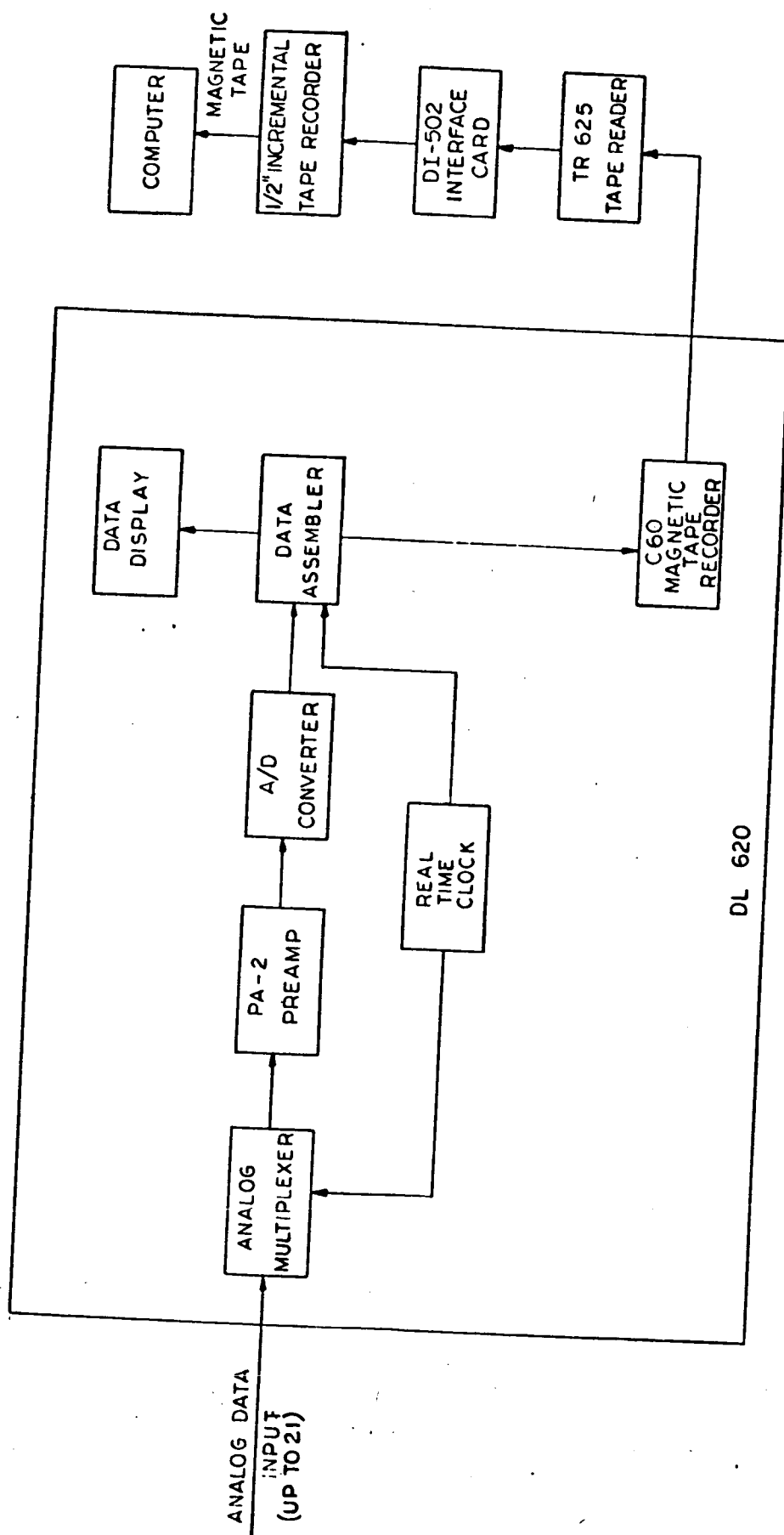


Figure A:4-10 Metrodata DL620/Cassette-Tape System Block Diagram

#### A-4.6.2 System Components

The Metrodata DL620/Cassette Tape System used to perform the data management function for the sunfall monitor will include the following hardware:

1. DL620 data logger
  - a. PA-2 preamplifier cards
2. Scaling networks to divide 0 - 240 millivolts and 0 - 8.0 volts sensor outputs to the 0 - 100 millivolt range for input to the DL620 digital data logger.
3. Calibration circuit to provide 50 millivolts to an unused channel of the data logger. This signal will be recorded and then used by the software as a standard reference for determining if a multiplying factor should be used to correct sunfall data due to a malfunction in the data management subsystem.
4. Thermocouple reference junction to provide accurate readings from thermocouples used in the system.
5. TR 625 tape reader.
6. DI502 cassette to 9 track interface card.
7. Cipher 100M-260 9 track tape recorder.

#### A-4.6.3 System Specifications

##### Metrodata DL620 Data Logger:

- |    |                                 |  |
|----|---------------------------------|--|
| 1. | Number of Data Channels:        | 21 Analog - Standard<br>Expandable to 72 analog channels in increments of 24 using the accessory AX-10 Analog Expansion Module   |
| 2. | Input Characteristics: Voltage: | $\pm 1.0$ volt full scale, all channels - standard<br>$\pm 10$ volts full scale, all channels - optional<br>$\pm 10$ millivolts $\pm 1$ volt full scale using the accessory PA-2 Preamplifier with 2 data channels per module. |
| 3. | Impedance:                      | 1 megohm - (differential)<br>1 megohm each terminal to ground  |
| 4. | Overvoltage Limit:              | $\pm 10$ Volts DC (without preamp).  |

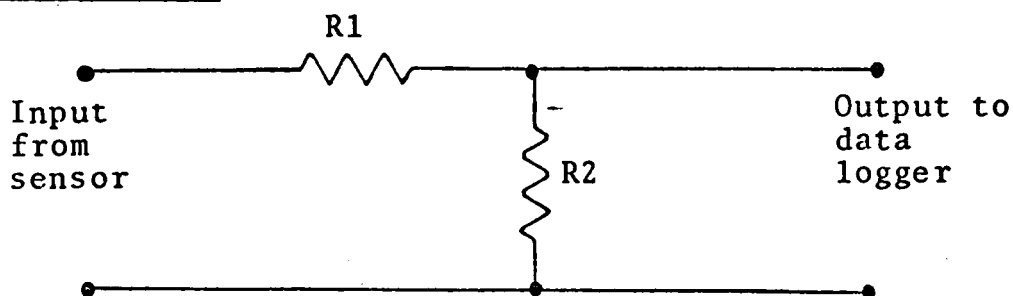
5. Resolution: 1 part in 1000 (0 to Full Scale)
6. Accuracy:  $\pm 0.1\%$   $\pm 1/2$  L.S.B. from 0° to 40°C  
 $\pm 1.0\%$   $\pm 1/2$  L.S.B. when using the PA-2 Preamplifier
7. Conversion Time: 10 Milliseconds
8. Data Scan Rate: (Selectable on order)

#### RECORDING FORMAT:

9. Tape Code: BCD Complement
10. Number of Tracks: 4
11. Packing Density: 67 Character/Inch - Standard  
200 Character/Inch - Optional
12. Data Format: 4 Bit Parallel Character
13. Channel Format: Sign Character and 3 BCD Characters
14. Sign Code: Plus (+) Character = 10  
Minus (-) Character = 11
15. Data Scan Sequence: Channel No. Information Characters  
 (One Record)  
 1 & 2 Time 8  
 3 - 20 Data 72  
 21-120 Data 4/Channel  
 (with AX-10)  
 Preparity 1  
 Parity 1
16. Parity Code: Preparity Character = 12 or 13  
Parity Character = Any number except 0
17. Parity: Longitudinal Even
18. Magnetic Tape Cartridge: Type C-60, Endless Loop, 1/4 x 1200', Lubricated Instrumentation Grade Tape with reflective BOT and EOT markers.
19. Tape Data Capacity: 200 C.P.I.  
Continuous Mode - Approximately 35,000 20 Channel records  
Intermittent & Remote Modes - Approximately 14,400 Dual 20 Channel records (two complete records are recorded each scan cycle)

- 67 C.P.I  
Continuous Mode - Approximately  
8,500 20 Channel records  
Intermittent & Remote Modes -  
Approximately 4,000 Dual 20 Channel  
records (two complete records  
are recorded each scan cycle)
20. BOT/EOT Sensor Photo Diode with front panel  
BOT/EOT indicator
21. Internal Clock: Crystal Controlled (1 MHz)  
Time Base
- Accuracy:  $\pm 2$  Seconds/Day
- Time Record: Days, Hours, Minutes, seconds  
from 000:00:00:00 to 999:23:59:59  
recorded each scan
22. Data Display: 3 digit NIXIE indicators display  
data from the switch selected  
channel
23. Data Polarity Display: Indicator Lamp ON when data is  
negative
24. Temperature Range:  $0^{\circ}$  to  $40^{\circ}\text{C}$ .
25. Humidity Range: 0% to 98% Relative Humidity,  
Non-Condensing
26. Altitude Range: 0 to 30,000 feet
27. Power Input:
- 117 VAC  $\pm 10\%$ , 50-400 Hz, 35 watts  
which will be converted to  
11.5 to 14 VDC, Recording Mode -  
2.4 Amps, Standby Mode - 160 m.a.
28. Dimensions: 11.0" wide x 8.3" high x 11.1" deep
29. Weight: 18 pounds

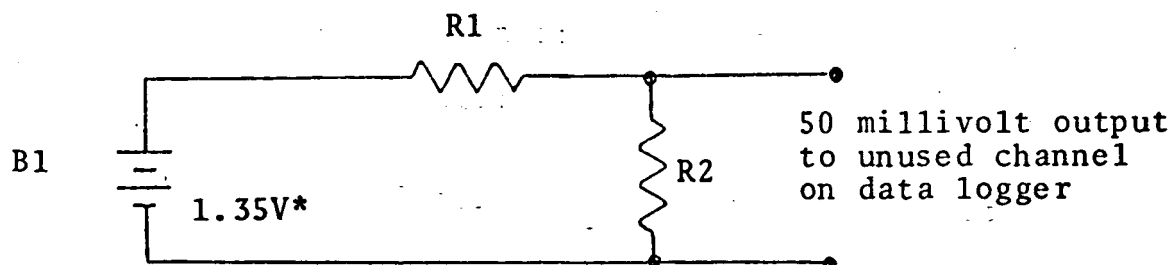
### Scaling Networks:



Input Voltage	R1	R2	Output Voltage
0 - 240 mV	RN60D2431F	RN60D1001F	0 - 100 mV
0 - 8.0 V	RN60D8062F	RN60D1001F	0 - 100 mV

Mount components on Cinch Jones 12-140 terminal board. Mount terminal board on rear of data logger or thermocouple reference junction, whichever is most convenient.

### Calibration Circuit:



### Parts:

- B1 - Mallory RM42R
- R1 - Resistor RN60D2742
- R2 - Resistor RN60D1001F
- H1 - Battery holder Cambion 2870
- TB1 - Terminal strip - Jones 10-140

\*Battery will be changed every 12 months.

### Hy-Cal 205-T Thermocouple Reference Junction:

1. Model 205-T
2. Reference Temperature: 150°F
3. Stability:  $\pm 0.1^{\circ}\text{C}$
4. Ambient temperature  $\Delta$  (-30 to + 120°F):  $\pm 0.25^{\circ}\text{F}$
5. Power: 115 VAC at 75 watts maximum
6. Input terminations: screw terminals
7. Output terminations: MS3102A connector
8. Type T (ISA)
9. Channels: 26
10. Size: 5 1/4" H x 17" W x 9" D (rack mount)

### TR625-2 Tape Reader:

#### DATA FORMAT

##### Tape-to-Tape Mode:

1. Output Format: 10 Bit parallel  
Bit Allocation Function  
1-2-3-4-5-6(7-8) Data Bits (9 track)  
9 Step/Record Command  
10 IRG Command
2. Input Format: 1 Bit  
Bit Allocation Function  
1 IRG Complete
3. 1/2 Inch Tape Format:  
Character 8 Bit EBCDIC (9 track)  
Block Block length can be adjusted  
from 1 character to 10,000  
characters in single steps  
and 10,002 to 20,000 characters  
in dual character steps.
4. Single Channel Display 3 digit display indicator for  
continuous display of channels  
selected by thumbwheel selector  
switch
5. Power Input 115 VAC  $\pm 10\%$  60 Hz, 30 watts

6.	Dimensions	11.0" wide x 8.3" high x 11.1" deep
7.	Weight	15 pounds
8.	Operation Temperature	0 to +40C
9.	Operation Humidity	0 to 95% relative humidity, non-condensing

Cipher Tape Recorder 100M-360:

1.	Reel size	10 1/2"
2.	Tape length	2400'
3.	Rewind time	6 min
4.	Incremental wire	0-600 char./sec.
5.	Inter Record Gap Time	175 msec. (50 msec. optional)
6.	Density	9-track: 800 bpi
7.	Speed accuracy	±1% long term, ±3% instantaneous
8.	Bit spacing accuracy (using internal optical encoder)	±2% typical (±4% worst case)
9.	File gap time	250 msec.
10.	Reel Drive	Reel Servos
11.	Capstan drive	DC motor with velocity and position servo
12.	Tape	1/2" wide, 1.5 mil thick
13.	Format	IBM compatible, 9-track, NRZI
14.	Local Control & Indicators	Power On/Off, load, ready, file gap, rewind
15.	Power	115VAC 50-60 Hz
16.	Panel height	24 1/2"
17.	Width	19"
18.	Depth	12 1/4"
19.	Weight	80 lbs.

#### A-4.6.4 System Cost

The prices stated here are based on the vendor quotation received at the time of inquiry and are provided only to show the relative cost of the Metrodata DL620/Cassette Tape Digital Data Logger System.

\$5,886	DL620 Data Logger
686	PA-2 Preamplifier
27	C60 Cassette Tape
76	RM-8 Rack Mount
17	Calibration Circuit
402	Thermocouple Reference Junction
<u>\$7,094</u>	

#### One Time Hardware Cost:

\$3,733	TR625-2 Tape Reader
415	DI502 Interface Card
5,817	Cipher 100M - 360
<u>\$9,965</u>	

#### A-4.6.5 Total Recording Time Calculations

##### Assumptions:

1. Data Density: 200 Character per inch
2. Tape Length: 1200 feet = 14,400 inches
3. Tape Speed: 1/2 inch per second for 24 channels per second
4. Motor start/stop time: 0.12 second - start  
0.13 second - stop
5. Scan Length: (16 channels/scan) x  
(4 character/channel) + parity  
+ preparity = 66 characters/scan

##### Gap Length:

Gap length results from tape movement while the motor is accelerating and decellerating before and after each 10 seconds scan.

Start/Stop distance = 0.125 inches

One scan distance =  $\frac{66 \text{ characters}}{200 \text{ characters/inch}}$  = 0.33 inch  
for 16 channels

Total distance/scan = 0.125" + 0.33" = 0.46 inch

TABLE C.1-1

## SENSOR CHARACTERISTICS - TRACKING AND NON-TRACKING ASSEMBLIES

FUNCTION	INSTRUMENT TYPE	SENSOR TYPE	MFG & DESIGNATION	SENSITIVITY $\text{mV/cal/cm}^2/\text{min}^{-1}$	LINEARITY	RESPONSE TIME	IMPEDANCE	TEMPERATURE DEPENDENCE	WHFP : USED	COST \$
Direct Component Reference Meas.	Pyrheliometer	Wire-Wound Thermopile	Eppley Model NIP	4-7	Linear up to $4\text{mV/cal/cm}^2/\text{min}^{-1}$	1 Second (1/e signal) (Note 1)	200 Ohms	$\pm 1\%$ from $-20^\circ\text{C}$ to $+40^\circ\text{C}$ (Note 2)	Tracking Assy	1170.00
Concentrator Output Meas	Pyrheliometer (Note 3)	Wire-Wound Thermopile	Eppley Model NIP	4-7	Linear up to $4\text{mV/cal/cm}^2/\text{min}^{-1}$	1 Second (1/e signal)	200 Ohms	$\pm 1\%$ from $-20^\circ\text{C}$ to $+40^\circ\text{C}$	Tracking Assy	1170.00
Total Radiation Reference Meas.	Pyranometer	Wire-Wound Thermopile	Eppley Model PSP	5	Linear up to $4\text{mV/cal/cm}^2/\text{min}^{-1}$	1 Second (1/e signal)	300 Ohms	$\pm 1\%$ from $-20^\circ\text{C}$ to $+40^\circ\text{C}$	Tracking and Non-Tracking Assy	1370.00
Solar Cell Test	Solar Cell Test Module	Cell of Interest	Special Design (Note 3)	TBD by Calibration	TBD by Calibration	TBD by Calibration	Variable 0.1 Ohms to 20 Ohms (Note 4)	TBD by Calibration	Tracking and Non-Tracking Assy	~ 500.00
Thermal Absorber Test	Absorber Test Module	Heat Flux Transducer Plus Material of Interest	Hy-Cal BI-7	171 (Heat Flux Transducer)	TBD by Calibration	TBD by Calibration	23K Ohms (Max)	TBD by Calibration	Tracking and Non-Tracking Assy	~ 500.00

## NOTES:

1. "e" is the base of natural logarithms. 1/e represents the fraction of maximum sensor output attained in one second.
2. Temperature compensation of sensitivity available over other ranges within the limits of  $-70^\circ\text{C}$  to  $+50^\circ\text{C}$ , at additional cost.
3. This pyrheliometer is used to measure reflected solar energy from samples of various concentrator materials.
4. A solar cell array consisting of one to nine 2 cm x 2 cm cells or a lesser number of larger cells can be accommodated by the solar cell test module. The test module contains a fixed resistor for current limiting and a variable resistor to allow change in the operating point of the array from near short circuit to open circuit conditions to allow flexibility of test conditions for the array under test.

Average tape speed = 0.46 inch/10 seconds = 0.046 inch/second.

Therefore, at 24 channels/second recording rate:

$$\text{Duration} = \frac{(14,400 \text{ inches})}{0.046 \text{ inch/second}} \times \frac{1 \text{ hour}}{(3600 \text{ (seconds)})}$$

$$\text{Duration} = 86.95 \text{ hours}$$

For a 15 hour recording day,

$$\text{Duration} = 5.79 \text{ days (15 hours/day)}$$

Less 10% due to various causes,

$$\text{Duration} = 5.21 \text{ days (15 hours/day)}$$

APPENDIX B

SOLAR TRACKER SUBSYSTEM  
VENDOR EVALUATION

B-1      VENDOR EVALUATION

This evaluation assigns weighting factors to establish a value relationship between the various tracker features. Each feature is then graded using the grade guideline sheet on page B-3. The resulting merit total thus represents an impartial rating for each device evaluated.

B-2      VENDOR SELECTION

The search for a suitable sunfall monitor tracker vendor narrowed from a field of 30 to 9 potentially capable organizations. Further investigation narrowed the selection to 4 for the fully automatic subsystem, and left only the Eppley Laboratory, Inc. of Newport, R.I. with a semi-automatic device available "off the shelf." With the fully automatic tracking problem more carefully defined, several of the 9 selected companies responded with a "no bid" reply. Two companies offered only a catalog line of equipment suitable only for use in a protected environment. The four companies found capable of supplying a fully automatic tracking subsystem were evaluated. The four companies are:

Carson Astronomical Instruments, Inc., Valencia, Calif.

Perkin-Elmer, Boller & Chivens Div., S. Pasadena, Calif.

Owens-Illinois, Fecker Systems Div., Pittsburgh, Penn.

Ball Brothers Research Corporation, Boulder, Colorado

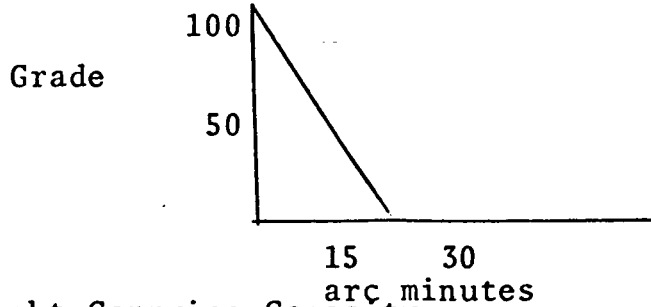
The Carson Astronomical Instrument company is recommended as the most suitable source for the Sunfall Monitor fully automatic sunfall tracker subsystem.

# SUNFALL MONITOR TRACKER EVALUATION GRADE

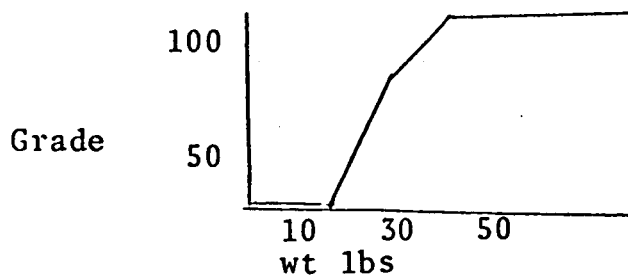
## GUIDELINES - FULLY AUTOMATIC

1. Two axis drive - yes = 100 no = 0

2. Pointing Accuracy



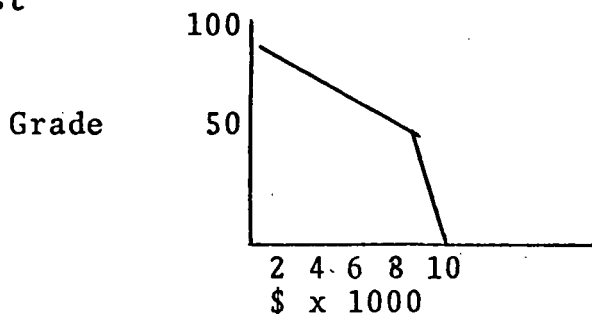
3. Weight Carrying Capacity



4. All weather capability - yes = 100 no = 0

5. Return to East - yes = 100 no = 0

6. Cost



7. Find sun after 2 minute power failure - yes = 100 no = 0

8. Find sun after 5 sunless days - yes = 100 no = 0

9. Reacquire sun within 5 minutes - yes = 100 no = 0

10. 30 day unattended operation - yes = 100 no = 0

11. Difficult to install - yes = 0 no = 100

12. Delivery time - < 10 weeks = 100, 12 - 16 weeks = 85  
16 - 24 weeks = 70, > 24 weeks = 0

# SUNFALL MONITOR TRACKER

Manufacturer: Ball Brothers Research Corporation

1. Two axis drive - yes
2. Pointing accuracy -  $\pm 1$  arc minute
3. Weight carrying capacity - 50 pounds
4. All weather capability - yes
5. Return to east - yes
6. Cost - \$14.4K
7. Find sun after 2 minute power failure - yes
8. Find sun after 5 sunless days - yes
9. Reacquire sun within 5 minutes - yes
10. 30 day unattended operation - yes
11. Difficult to install - no
12. Delivery time - 4 months

Characteristic	1	2	3	4	5	6	7	8	9	10	11	12
Weight factor	.12	.12	.08	.12	.10	.10	.06	.06	.06	.06	.06	.06
Evaluat. Grade	100	100	100	100	100	0	100	100	100	100	100	70
Merit Value	12	12	8	12	10	-	6	6	6	6	6	4.2
Merit Total												88.2

FULLY AUTOMATIC

# SUNFALL MONITOR TRACKER

Manufacturer: Carson Astronomical Instrument Co.

Model: Mod 605 Mount & Mod 830 Guider

1. Two axis drive - yes
2. Pointing accuracy -  $\pm 30$  arc seconds
3. Weight carrying capacity - 75 pounds
4. All weather capability - yes
5. Return to east - yes
6. Cost - \$7.9K
7. Find sun after 2 minute power failure - yes
8. Find sun after 5 sunless days - yes
9. Reacquire sun within 5 minutes - yes
10. 30 day unattended operation - yes
11. Difficult to install - no
12. Delivery time - 4 months

Characteristic

Weight factor

Evaluat. Grade

Merit Value

Merit Total

1.	2	3	4	5	6	7	8	9	10	11	12
.12	.12	.08	.12	.10	.10	.06	.06	.06	.06	.06	.06
100	100	100	100	100	70	100	100	100	100	100	70
12	12	8	12	10	7	6	6	6	6	6	4.2

95.

FULLY AUTOMATIC

# SUNFALL MONITOR TRACKER

Manufacturer: Owens-Illinois Fecker Systems Division

1. Two axis drive - yes
2. Pointing accuracy -  $\pm 20$  arc minutes
3. Weight carrying capacity - 50 pounds
4. All weather capability - yes
5. Return to east - yes
6. Cost - approximately \$62K
7. Find sun after 2 minute power failure - yes
8. Find sun after 5 sunless days - yes
9. Reacquire sun within 5 minutes - yes
10. 30 day unattended operation - yes
11. Difficult to install - yes
12. Delivery time - ?

Characteristic	1	2	3	4	5	6	7	8	9	10	11	12
Weight factor	.12	.12	.08	.12	.10	.10	.06	.06	.06	.06	.06	.06
Evaluat. Grade	100	20	100	100	100	0	100	100	100	100	0	100
Merit Value	12	2.4	8	12	10	-	6	6	6	6	-	6
Merit Total	74.4											

FULLY AUTOMATIC

# SUNFALL MONITOR TRACKER

Manufacturer: Perkin-Elmer Boller & Chivens Division

1. Two axis drive - yes
2. Pointing accuracy -  $\pm$  3 arc minutes
3. Weight carrying capacity - 50 pounds
4. All weather capability - yes
5. Return to east - yes
6. Cost - \$11K
7. Find sun after 2 minute power failure - yes
8. Find sun after 5 sunless days - yes
9. Reacquire sun within 5 minutes - yes
10. 30 day unattended operation - yes
11. Difficult to install - yes
12. Delivery time - 16 - 24 weeks

Characteristic	1.	2	3	4	5	6	7	8	9	10	11	12
Weight factor	.12	.12	.08	.12	.10	.10	.06	.06	.06	.06	.06	.06
Evaluat. Grade	100	90	100	100	100	70	100	100	100	100	0	70
Merit Value	12	10.8	8	12	10	7	6	6	6	6	-	4.2
Merit Total	88.0											

FULLY AUTOMATIC

## APPENDIX C

## SENSOR CHARACTERISTICS

## SECTION C-1

### SUMMARY

The Sunfall Monitor detection/comparison subsystem includes both conventional radiation measuring instruments and specially designed test modules for the evaluation of thermal absorber, solar concentrator and solar cell samples. The former measure available solar energy in tracking and non-tracking modes of operation while the latter measure the usable energy when converted by the three classes of converter. Table C.1-1 gives the primary characteristics of these instruments and test modules to the extent they are known prior to calibration of an operating unit.